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THE ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY AND ASTRONOMICAL PHYSICS

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VOLUME LX DECEMBER 1924 NUMBER 5

MEASUREMENT OF THE INTENSITY OF THE LIGHT OF THE CORONA AT THE ECLIPSE OF SEPTEMBER 21, 1922

By G. H. BRIGGS

ABSTRACT

Method of measurement.—Measurements of the total intensity were made at Goondiwindi, Queensland, with two photo-electric cells by a method similar to that used by Kunz and Stebbins in 1918.

Results.—With each cell it was found that there was a maximum at the beginning and at the end of totality. The results obtained with cell 1 showed changes in intensity, in Hefner candle-meters, from 0.37 for the first reading to 0.23 at mid-totality and to 0.29 just before the end of totality. With cell 2 the corresponding results were 0.34, 0.22, and 0.27. Reduced to no atmosphere, these become 1.02, 0.64, and 0.81 for cell 1, and 0.95, 0.61, and 0.72 for cell 2. In Table III the results of a comparison of the corona and the full moon are given.

Photographic confirmation of variations.—In support of the reality of the variations observed, reproductions of prints made from negatives obtained at Goondiwindi by James Nangle are given in Plate I. These show that very bright portions of the corona which were visible near second and third contacts were covered by the moon during mid-totality.

Measurement of the total intensity of the light of the corona at the eclipse of the sun of September 21, 1922, formed part of the work of the Eclipse Expedition from the University of Sydney to Goondiwindi, Queensland.

The method employed was similar to that of Kunz and Stebbins,[1] who in 1918 measured the light of the corona by means of a photo-electric cell.

[1] *Astrophysical Journal*, **49**, 137, 1919.

On the present occasion two photo-electric cells were used having active surfaces of potassium and containing helium. It was found that these were sufficiently sensitive to light to enable the currents that were to be expected during totality to be measured by a sensitive galvanometer. Each of the cells had a glass bulb 4 cm in diameter and an opening of clear glass 3 cm in diameter to admit light. The cells were mounted in wooden boxes each of which had a diaphragm with a circular aperture 2.92 cm in diameter. The boxes were attachable to the lower ends of tubes 1 meter long. The tube for cell 1 was made of wood and had a square section 12×12 cm and a circular opening at the upper end 9.65 cm in diameter. The tube for cell 2 was circular in section and its diameter 13 cm; and the opening at the upper end was 10.2 cm in diameter. Inside each tube there were diaphragms to prevent light reflected from the sides from entering the cell. It may readily be shown that any point of cell 1 was illuminated by a circle of diameter $5\overset{\circ}{.}53$, and that the clear field was a circle of diameter $3\overset{\circ}{.}86$, which was sufficient to include the whole of the corona and to allow for the motion, $0\overset{\circ}{.}87$, during the 210 seconds of totality. For cell 2, the corresponding circles were slightly greater than for cell 1. The tube for cell 1 was set on an alt-azimuth mounting with stops arranged so that it could be pointed at the position of mid-totality or rotated in azimuth 10° to the east to obtain readings of the sky alone. The tube for cell 2 was mounted independently, and was rotated a similar distance toward the zenith about a horizontal axis, for readings of the sky.

Each circuit consisted of cell, galvanometer, high resistance, and battery in series. Leeds-Northrup moving coil galvanometers were used, the deflection being read with lamp and scale at a distance of about 2 meters. The galvanometer for cell 1 had a sensitivity of 2.2×10^{-11} amperes per millimeter deflection at a scale distance of 1 meter; and that for cell 2, 2.0×10^{-11} amperes per millimeter. The times taken by the spot of light to arrive at its resting-point when critically damped were approximately 20 and 15 seconds, respectively. High resistances of 1 and 5 megohms were used to protect the photo-electric cells. A battery of eighty small 3-volt dry cells was available for the potentials required for the photo-electric cells. The positive end of this battery was earthed,

and during the observations of the corona a potential of 185.6 volts was applied to cell 1 and 161 volts to cell 2. The dark currents were reduced to a very small amount by providing each cell with an earthed guard-ring on the arm which carries the grid.

Kunz and Stebbins in their measurement of the brightness of the corona used as their main standard of light an amyl-acetate or Hefner lamp and expressed their results by using this lamp as the unit. A Hefner lamp could not be obtained for the work at Goondiwindi; and though, through the courtesy of Professors Fawsitt and Madsen, pentane standard lamps of 1 and 10 candle-power were lent, these were not taken to the eclipse station. It was decided to use low-voltage electric lamps as subsidiary standards. Difficulty was experienced in obtaining suitable lamps of sufficiently low candle-power. Two candle-power 6-volt motor-car lamps were finally chosen, and it was thought that if these were well aged and run at low currents they would prove sufficiently constant. Provision was made for attaching these lamps to the lids of the exposure tubes, and readings could be taken in daylight, and just before and just after the period of totality. Nine of these lamps were used, and the intensity of the light of each was measured by means of the photoelectric cells at 5 currents from 0.38 to 0.42 ampere, and occasionally at lower currents, in terms of the 10 candle-power pentane standard. Unfortunately, there was not time before the eclipse to test these lamps out as thoroughly as could be desired, and it appears now that in some cases there were appreciable changes in candle-power.

The lamps have been measured since our return at various times over an interval of about twelve months, and it has been found that the majority remain consistently constant, but some are apparently liable to fluctuation. Four lamps were used in the readings just before and after totality, and two of these were afterward found to be unsteady. On this account, the accuracy of the results is probably not more than 10 or 15 per cent.

On return to the laboratory, the relationship between current and light-intensity for the two cells was found by observing the deflections caused by an electric lamp run at constant current at various distances from the cell. Definite departures from a linear relationship were found, and it was discovered further that the

form of the curve varied from time to time. Since it had been the custom, when making measurements of the candle-powers of the lamp by means of the photo-electric cells, to use a wide range of currents, it was possible to obtain the calibration curve for the cells corresponding to any previous set of observations by plotting the deflection obtained for a lamp at the various currents against the corresponding candle-power. When these curves had been found and corrections applied from them to the observed intensities of the

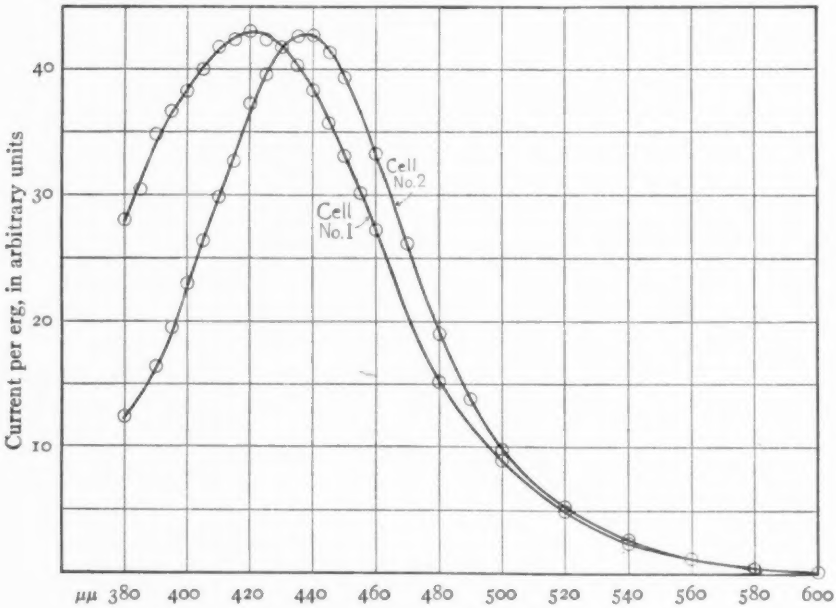


FIG. 1.—Color-sensitivity curves of the photo-electric cells

lamps, measured at different times after return, inconsistencies disappeared in the values obtained for most of the lamps.

The curves of color-sensitiveness for the two cells were found by means of a Hilger monochromatic illuminator. The two curves are shown in Figure 1. The maximum sensitivity for cell 2 occurs at 438 $\mu\mu$, and the curve for it is very similar to that for the cell used by Kunz and Stebbins except that according to our measurements its sensitivity does not fall off so rapidly on the side of the maximum toward short wave-length. The maximum for cell 1 is at 420 $\mu\mu$, and this cell is more sensitive to the blue end of the spectrum than

cell 2. At one stage it was thought that stray light in the monochromatic illuminator caused the readings to be unduly high on the side of the maximum toward short wave-length. Further investigation showed that the effect of such stray light was almost negligible. In the photometry of the lamps and in the measurement of the brightness of the moon, which will be described later, no appreciable differences were found in the results obtained by the two cells. This is to be ascribed to the rapid falling off in energy in the portion of the spectrum of the lights compared where the curves differ most.

In Tables I and II are given the results obtained by the two cells. Column 1 gives the approximate times from second contact at which the readings were made, the whole time of totality being 210 seconds. Columns 3 and 4 give the readings as observed and the corresponding deflection, allowance being made for the zero shift. Column 5 gives the deflections when corrected by the calibration curve of the cell, and the remaining columns give the intensities of the corona and sky in Hefner and pentane units. In Table I the value 0.030 for the sky in column 7 has been neglected and the mean of the remaining three readings used in deducing the light of the corona alone. In Table II the mean sky value again has been used. In the case of cell 1 two observations of the light of the corona were taken with filters placed in the path of the light just in front of the cells. The two filters used were a Wratten H blue filter and a Wratten B green filter. These filters were of the usual kind, the absorbing gelatine being mounted between glass. The results obtained are given in the table.

The results obtained for the brightness of the corona are given in pentane and Hefner candle-meters. The conversion to Hefner units was made in the following way: a Hefner lamp was constructed in the laboratory and when visually measured against the pentane standard with the photometer its candle-power was found to be 0.974. When measured by means of the photo-electric cells the result was 0.764 c.p., the difference, of course, being due to the difference in quality of the two lights. The accepted visual value of a Hefner lamp appears to be 0.9 pentane candle so that our Hefner lamp was about 7 per cent too high. It is unlikely, however, that the quality of the light from this Hefner lamp differs appreciably

from that of a standard Hefner; so we conclude that a standard Hefner measured by the photo-electric cells is equivalent to $\frac{0.764 \times 0.9}{0.974} = 0.706$ pentane candles. In the tables the values in Hefner units have been determined by dividing the pentane values by this factor.

It has been the custom to express the intensity of the corona in terms of that of the full moon. Observations of the moon's intensity

TABLE I

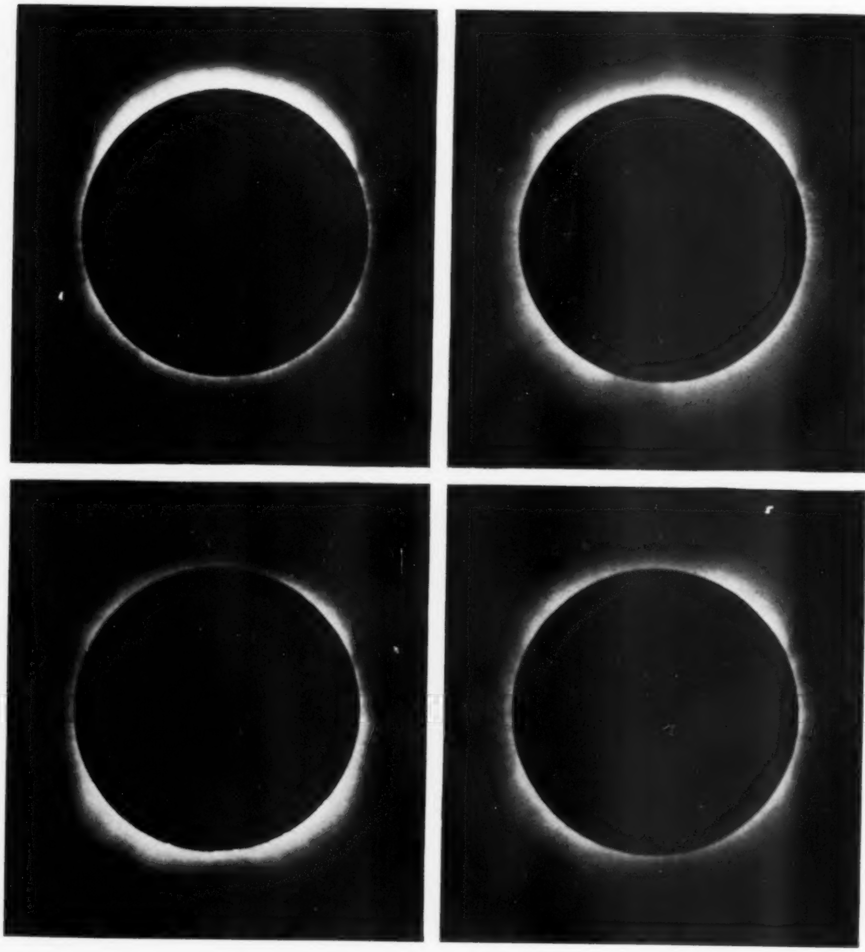
CELL 1

Time in Seconds	Exposure to	Galvanometer Reading	Deflection	Corrected Deflection	Brightness in Candle-Meters: Unit = Hefner Candle-Meter			Unit = Pentane Candle-Meter
					Corona +Sky	Sky	Corona Alone	Corona Alone
		cm	cm	cm				
....	Dark	10.00	0.00	0.00	....	....	....	....
25........	Corona+sky	13.10	3.11	3.11	0.443	....	0.366	0.258
45........	Same with H filter	10.82	0.85	0.78	0.111	....	....	....
65........	Same with B filter	10.18	0.24	0.22	0.031	....	....	....
85........	Sky	10.45	0.46	0.42	....	0.060	....	....
105........	Corona+sky	12.12	2.21	2.14	0.305	....	0.228	0.161
125........	Sky	10.57	0.67	0.63	....	0.090	....	....
145........	Corona+sky	12.45	2.57	2.52	0.360	....	0.283	0.200
165........	Sky	10.10	0.23	0.21	....	0.030	....	....
185........	Corona+sky	12.49	2.64	2.59	0.370	....	0.293	0.207
205........	Sky	10.45	0.61	0.56	....	0.080	....	....
225........	Dark	9.84	0.00	0.00	....	....	....	....
Mean...	....	....	....	....	....	0.077	0.29	0.21

as measured by the cells are given in Table III. The method of allowing for absorption of light by the earth's atmosphere is the same as that used by Kunz and Stebbins. In this calculation their factor, 1.8 for a potassium cell on a clear night, has been used, since the sky was particularly clear on both the occasion of the eclipse and on the nights when the moon's intensity was measured. The result obtained for the full moon, 0.225, is in fair agreement with their value of 0.213. Their values, corrected to no atmosphere, for the corona and for the ratio of corona to full moon, 1.07 Hefner candle-

PLATE IV

a b



d c

INNER PORTION OF CORONA OF SEPTEMBER 21, 1922

Photograph	Exposure	Approximate Time after Second Contact of Mid-Point of Exposure
a	3 seconds	13 seconds
b	12	60
c	24	90
d	12	195

Period of totality 210 seconds

meters and 0.50, respectively, are somewhat higher than the maximum values found on this occasion.

Although a high degree of accuracy cannot possibly be claimed for the results when expressed in candle-meters, owing to the trouble with the comparison electric lamps and to the changing of the calibration curves of the cells, one noteworthy thing shows up in the results. With both cells the maximum intensity of the corona was

TABLE II

CELL 2

Time in Seconds	Exposure to	Galvanometer Reading	Deflection	Corrected Deflection	Brightness in Candle-Meters			
					Unit = Hefner Candle-Meter			Unit = Pentane Candle-Meter
					Corona +Sky	Sky	Corona Alone	Corona Alone
		cm	cm	cm				
10	Dark	13.3	0.00	......	....	....	....	....
30	Corona+sky	15.55	2.25	2.25	0.420	....	0.340	0.240
45	Sky	13.92	0.60	0.55	....	0.105	....	....
60	Corona+sky	15.30	1.90	1.88	0.347	....	0.267	0.188
75	Sky	13.90	0.45	0.41	....	0.081	....	....
90	Corona+sky	15.35	1.85	1.83	0.339	....	0.259	0.183
110	Dark	13.50	0.00	......	....	....	....	....
130	Corona+sky	15.18	1.66	1.61	0.304	....	0.224	0.158
145	Sky	13.85	0.30	0.28	....	0.051	....	....
175	Corona+sky	15.47	1.85	1.83	0.339	....	0.259	0.183
190	Sky	14.15	0.45	0.41	....	0.081	....	....
205	Corona+sky	15.55	1.85	1.83	0.339	....	0.259	0.183
225	Dark	13.75	0.00	......	....	....	....	....
Mean	....	....	......	......	....	0.08	0.27	0.19

found to occur at the beginning of the observations, and to be followed by a minimum near the middle of totality, after which the intensity rose again but did not reach the initial value. There seems to be no doubt that this change did occur and is not to be accounted for by the rather large changes which took place in the zeros of both galvanometers. In support there is very definite evidence furnished by photographs of the corona taken by James Nangle and developed by E. H. Booth, who were members of the expedition. A coelostat was used to reflect the light into the telescope, hence the photographs are "mirror-images." Prints from four of these negatives are shown in Plate IV in which the

times of printing have been made so long that only the inner portion of the corona appears; the original negatives show the corona extending far out from the sun. If printed for longer times than has been done in those here reproduced, *a* would show a series of very small prominences over an arc of about 90° at the top of the photograph, none being visible elsewhere; and *d* would show only a

TABLE III

OBSERVATIONS OF THE MOON AND THE RATIO OF THE CORONA TO FULL MOON

G.M.T.	Zenith Distance	Moon's Light in Hefner Candle-Meters	Reduction Factor to No Atmosphere	Corrected Moon's Light	Mean in Hefner Candle-Meters	Phase
1923 Oct. 24 $23^h\ 0^m$	62°	0.86	2.48	1.85	....	....
23 54	54	1.00	1.80	1.79	....	....
25 0 20	50	1.07	1.71	1.83	....	....
0 57	48	1.10	1.66	1.83	1.83	10°
Nov. 21 23 5	50	0.96	1.71	1.64	....	....
22 0 18	49	1.05	1.67	1.75	....	....
0 44	48	1.08	1.65	1.79	1.73	−13
23 0 37	52	1.27	1.76	2.24	....	....
0 53	51	1.32	1.74	2.29	....	....
2 58	53	1.26	1.77	2.23	2.25	0
Corona on Sept. 20, 1922	69	0.37 1st max.	2.79	1.02	....	Cell 1
	....	0.23 min.	....	0.64	....	....
	....	0.29 2d max.	....	0.81	....	....
	....	0.34 1st max.	....	0.95	....	Cell 2
	....	0.22 min.	....	0.61	....	....
	....	0.26 2d max.	....	0.72	....	....

Ratios of corona to full moon:

0.45 1st max.
0.28 min.
0.36 2d max. Cell 1

0.42 1st max.
0.28 min.
0.32 2d max. Cell 2

somewhat similar series but at the bottom. Some of these small prominences are visible in *d* as here reproduced. In *b* and *c* the prominences are wholly covered by the moon, and the coronal light is much more uniformly distributed around the disk than in *a* and *d*. Printing the negatives in this way shows clearly that the intensity of the corona increases very rapidly as the sun's limb is approached. It is evident that near the middle of totality not only were the

prominences covered but also the brightest portion of the inner corona, and hence the higher results obtained at the beginning and end of totality appear to be due in part to the uncovering of portions of this very bright region of the corona.

Kunz and Stebbins conclude that in their measurements the prominences contributed very little as the brightest lines of the spectrum of the prominences, the H and K calcium lines, 397 $\mu\mu$ and 393 $\mu\mu$, were almost without effect on their cell. In the present case, photograph *b* shows that the prominences were invisible near the middle of totality, so that the fact that a greater variation was found with cell 1 than with cell 2 may be due to the greater effect of the prominences on the former cell. That this is possible is readily seen from the curves of color-sensitivity of the cells. However, as the prominences were extremely small, the greater part of the variation was most probably due to the covering of the bright inner corona by the moon. It is concluded, then, that measurements of the total intensity of the corona made at different eclipses will depend not only on any variations in the brightness of the corona itself but also on the portion which is covered by the moon's disk. Thus the highest results would be expected when the observer is in the center of the path of totality, and the period of totality is short. In this connection it is to be noted that the period of totality when Kunz and Stebbins made their observations was 95 seconds, and their result is higher than the maximum value found on the present occasion.

The writer wishes to record his appreciation of the encouragement and help given by Professor O. U. Vonwiller, the leader of the expedition, at whose suggestion this work was undertaken. To Mr. James Mangle acknowledgment is due for the use of the corona negatives. Mr. R. L. Aston generously undertook to make the observations with cell 2 and gave valuable assistance in the final adjustments of the apparatus. To Mr. A. B. B. Ranclaud I am indebted for help in part of the preliminary photometry of the lamps, and to my wife for help in the initial testing of the cells and in the measurements of the moon.

The expense of this work was largely defrayed by a grant from the McCaughey Research Fund.

Physical Laboratory
University of Sydney, New South Wales
April 1924

THE ELECTRIC FURNACE SPECTRA OF VANADIUM AND CHROMIUM IN THE ULTRA-VIOLET[1]

By ARTHUR S. KING

ABSTRACT

Furnace spectra of vanadium, λ 2340–λ 3185, and of chromium, λ 2362–λ 3575.—This paper supplements *Mount Wilson Contribution*, No. 94, which covered these spectra from the foregoing limits into the red. Temperature stages of 2000°, 2300°, and 2600° C. were employed to observe the initial appearance and rate of increase in intensity of the ultra-violet lines to about λ 2700, while for shorter wave-lengths the absorption furnace was compared with the arc. The tables give the temperature classification of 515 vanadium and 640 chromium lines and their relative intensities in arc and furnace. New wave-lengths are given for 133 vanadium and 94 chromium lines which have not been measured in the arc spectrum or for which, owing to diffuseness or blends, the previous wave-lengths are poor. Comparison photographs of the spark spectrum were made for the selection of enhanced lines. Many enhanced lines of vanadium are emitted by the furnace, while those of chromium require, for the most part, the higher excitation of the arc for their initial appearance. In the discussion, mention is made of notable groups of low-temperature and high-temperature lines, also of the phenomena of reversal and dissymmetry in the condensed spark.

This paper supplements a previous one on the spectra of vanadium and chromium,[2] which covered the visible spectrum and reached ultra-violet limits for the two spectra at λ 3165 and λ 3550, respectively. The present tables of furnace lines extend to about λ 2340. As far as possible, emission spectra for three temperature stages of approximately 2000°, 2300°, 2600° C. have been used, and the intensities have been listed for these furnace temperatures and for the arc spectrum. A comparison with the spark spectrum served to select the enhanced lines. As in previous papers on furnace spectra, a classification has been made according to the temperature at which a line appears and its rate of growth with increase of temperature.

The emission spectra, extending to about λ 2700 for vanadium and λ 2800 for chromium, were made in the second order of a 15-foot concave grating, the scale of which is 1.86 A per millimeter. For shorter wave-lengths, the furnace material consists of absorp-

[1] *Contributions from the Mount Wilson Observatory*, No. 283.

[2] *Mt. Wilson Contr.*, No. 94; *Astrophysical Journal*, **41**, 86, 1915.

tion spectra of the two elements, obtained by placing a graphite plug in the furnace tube behind the powdered metal to be vaporized. The temperature of this plug was held at 3000° C. According to former observations,[1] the temperature of the absorbing vapor should then be near 2600°, and the resulting spectrum is to be rated as one of high temperature. By comparing the absorption lines in this region with those above λ 2800, where data for the emission spectra at three temperatures were also available, the classification was made to correspond as closely as the material permitted. For chromium, a low-temperature absorption spectrum beginning at λ 2726 was also obtained by the use of a tungsten lamp, with quartz window behind the furnace when the latter, with unobstructed tube, contained chromium vapor at 2000°. Absorption lines appearing in this spectrum may safely be placed in Classes I and II, and lines of shorter wave-length have been judged on the same basis, the degree to which they maintain their strength indicating their probable class.

Wave-lengths, either new or better than those thus far available for the arc spectrum, are given as measured by the writer for 133 lines of vanadium and 94 of chromium. Some of these measurements resulted from the resolution of close lines, some are for faint lines which are strengthened in the furnace, while others are for diffuse lines not previously measured in the arc, which are usually much sharpened in the vacuum furnace.

EXPLANATION OF THE TABLES

Tables I and II contain vanadium lines which appear with fair strength in the arc spectrum, Table I being for the region where only the arc and absorption furnace are available for comparison, while Table II gives intensities for the arc and for three temperatures of the emission furnace. Tables III and IV treat the chromium spectrum in the same way.

Wave-lengths.—International wave-lengths to two decimal places are given in the first column of each table. These are reduced from the values of Exner and Haschek except for lines marked with a dagger, which were measured by the writer. An asterisk after

[1] *Mt. Wilson Contr.*, No. 174; *Astrophysical Journal*, **51**, 13, 1920.

the wave-length refers to a note at the end of the table, explaining some peculiarity of the line.

Arc and furnace intensities.—Intensity estimates for lines in the arc and at three furnace temperatures are given in the four succeeding

TABLE I

VANADIUM LINES IN ARC AND ABSORPTION FURNACE

λ (I.A.)	Arc	Absorption Furnace	Class	λ (I.A.)	Arc	Absorption Furnace	Class
2340.49....	15	1	IV	2554.87.....	4	1	III
2399.97....	10	1	IV	2556.01.....	2	tr	III
2401.89....	10	1	IV	2556.79†....	1	tr	III
2406.7*†...	15	2	III	2558.92.....	3	1	III
2407.94....	8	1	III	2562.16.....	15	3	III
2412.72....	10	2	III	2564.29.....	6	1	III
2413.06....	8	1	III	2564.84.....	10	2	III
2415.35....	10	2	III	2574.05.....	20	4	III
2416.75....	15	3	III	2577.28.....	5	1	III
2417.36....	10	2	III	2602.7†.....	1	tr	III
2420.16....	12	2	III	2607.75†....	2	1	III
2421.08....	12	2	III	2611.75†....	1	tr	III
2422.01....	12	2	III	2614.90†....	2	1	III
2428.31....	12	2	III	2620.28.....	4	tr	III
2432.01....	10	2	III	2632.15†....	2	1	III
2435.52....	12	2	III	2637.15*....	5	2	III
2439.12....	6	1	III	2640.4†.....	2	1	III
2441.36....	2	1	III	2642.24.....	12	3	III
2441.91....	4	1	III	2643.13.....	10	3	III
2480.64....	3	1	III	2645.23.....	10	3	III
2482.14....	4	2	III	2647.70.....	15	5	III
2482.75....	2	1	III	2651.86.....	15	5	III
2483.65†...	2	1	III	2652.86.....	4	tr	IV
2498.08....	3	1	III	2653.79.....	4	tr	IV
2498.24....	3	1	III	2656.16.....	20	6	III
2499.24....	2	1	III	2661.39.....	20	6	III
2501.66....	8	2	III	2665.94.....	6	2	III
2503.34....	5	2	III	2670.94.....	2	1	III
2505.57†...	2	1	III	2671.65.....	8	2	III
2507.85*...	15	3	III	2671.99.....	20	tr	V E
2510.28....	2	1	III	2675.73.....	3	1	III
2511.65....	8	2	III	2677.10.....	1	tr	III
2511.97....	8	2	III	2677.77.....	25	tr	V E
2515.16....	5	1	III	2678.55*....	25	4	III
2517.14....	8	2	III	2679.30.....	25	tr	V E
2519.60....	15	3	III	2682.89.....	20	....	V E
2521.56*...	4	1	III	2683.10.....	20	tr	V E
2526.21....	12	4	III	2685.12.....	4	1	III
2530.18....	15	3	III	2686.51.....	8	3	III
2543.73....	4	1	III	2687.95.....	35	1	V E
2545.93....	20	3	III	2688.70.....	20	tr	V E
2549.26....	8	1	III	2689.89.....	20	tr	V E
2549.62†...	3	1	III	2690.27.....	25	tr	V E
2552.63....	10	2	III	2690.80.....	25	tr	V E

TABLE II

TEMPERATURE CLASSIFICATION OF VANADIUM LINES

λ (I.A.)	Arc Int.	Furnace Intensities High Temp.	Furnace Intensities Medium Temp.	Furnace Intensities Low Temp.	Class	λ (I.A.)	Arc Int.	Furnace Intensities High Temp.	Furnace Intensities Medium Temp.	Furnace Intensities Low Temp.	Class
2696.21	1				V	2776.47	6n	1			IV
2696.76	2	1			IV	2776.67†	2n				V
2696.99	15	3	tr		IV	2777.70*	8n	2			IV
2697.71	15	3	tr		IV	2778.03	4	3			IV
2698.70	12	2	tr		IV	2783.76	7	1			IV
2699.07	8	1			IV	2785.52	8	2			IV
2700.91	20	1			V Eru	2785.66	10	3			IV
2701.25	3	1			IV	2788.16	2				V
2701.51	1				V	2797.02	1				V E
2702.14	15				V E	2798.75	1				V E
2705.16	2				V E	2799.45	2				V E
2706.11	20	tr			V Eru	2802.77	1				V E
2706.63	8				V E	2803.45	3				V E
2707.82	5				V E	2810.24	2				V E
2711.73	6				V E	2815.97	5n				V
2713.04	4				V E	2817.49	2				V E
2714.15	6				V E	2834.88	3				V
2714.99	4				V	2835.64	5	tr			V
2715.65	8				V E	2836.49	2				V E
2721.11	6	1			IV	2836.65	3	5	1		IV
2722.54	15	3	tr		IV	2838.06	5	5	2		III
2723.20	2				V E	2839.43	4	tr			IV
2728.59	10				V E	2841.04	2				V E
2731.33	40	5	1		IV	2844.92	2	tr			IV
2731.49	15n	1			IV	2845.22	1				V
2733.34	3	3	tr		IV	2846.55	20	5	tr		IV
2733.90	2				V E	2847.59	1				V
2739.70	5				V E	2848.74	15	6	4	2	II
2742.41	3				V E	2849.14	15	6	4	2	II
2742.67	3				V E	2850.74	1				V
2743.77	1				V	2851.79*	20	10	12	4	II
2747.50*	5	4	1		III	2852.88	25	5	tr		IV
2753.08	3				V	2853.54	2				V
2753.41	2				V E	2853.82	3n	2			IV
2755.64*	5	tr			V	2854.01	4n	2			IV
2757.75	2				V	2854.32	2				V E
2760.13	2				V E	2855.21	20	10	6	2	II
2760.69	2				V E	2855.48	6	4	tr		IV
2765.66	5				V E	2855.64	2	1			IV
2766.10	1				V	2857.98	20	8	1		IV
2766.45	4	1			IV E	2858.79	10	5			IV
2768.30	3	tr			IV	2859.00	4n	2			IV
2768.55	3				V E	2859.99	25	10r	4	2	II
2768.93	6	2	tr		IV	2861.67*†	1	tr			IV
2770.94*	2	tr			IV	2862.45	10	5	tr		IV
2773.66	8	3			IV	2863.06	12	6	tr		IV
2774.01	3	1			IV	2864.38	30r	12r	5	3	II
2774.27	2				V E	2866.41	20	10	2		IV
2775.75	1				V	2866.60	15	8	1		IV

TABLE II—*Continued*

λ (I.A.)	Arc Int.	Furnace Intensities: High Temp.	Furnace Intensities: Medium Temp.	Furnace Intensities: Low Temp.	Class	λ (I.A.)	Arc Int.	Furnace Intensities: High Temp.	Furnace Intensities: Medium Temp.	Furnace Intensities: Low Temp.	Class
2866.95	10	5	1	.....	IV	2920.07†	6	.....	.....	.....	V E
2868.12	20	10	1	.....	IV	2920.40	8	1	.....	.....	IV E
2869.15	1	.....	.....	.....	V	2921.18†	6n	1	.....	.....	IV
2869.49	3	2	.....	.....	IV	2922.64	4	10	8	.....	III A
2870.04	5	3	.....	.....	IV	2922.76†	5n	1	.....	.....	IV
2870.57	35r	15r	8	5	II	2923.41†	2n	.....	.....	.....	V
2875.68	2	.....	.....	.....	V E	2923.60	70R	35r	15r	8	II
2877.68	2	.....	.....	.....	V	2924.01	30	12	tr	.....	IV Er
2879.15*	5	.....	.....	.....	V E	2924.61	25	8	tr	.....	IV Er
2880.04	10	tr	.....	.....	V E	2924.92†	5n	2	.....	.....	IV
2882.51	12	1	.....	.....	V E	2925.32	1	.....	.....	.....	V E
2884.79	12	1	.....	.....	V E	2925.86	4	10	5	.....	III A
2887.69	2	5	2	.....	III A	2926.23	12	12	12	10	I
2888.23	3	.....	.....	.....	V E	2927.62†	10n	3	.....	.....	IV
2888.50	2	5	2	.....	III A	2928.62	2	1	.....	.....	IV
2889.62	12	1	.....	.....	V E	2928.74†	1n	tr	.....	.....	IV
2890.56†	5N	1	.....	.....	IV	2930.14	1	.....	.....	.....	V E
2891.37†	2n	1	.....	.....	IV	2930.78†	15	3	.....	.....	IV Er
2891.65	15	2	.....	.....	IV Er	2930.89†	15n	5	.....	.....	IV
2891.94†	2n	2	.....	.....	IV	2932.34	1	.....	.....	.....	V E
2892.44	15	1	.....	.....	V Er	2933.20†	3n	1	.....	.....	IV
2892.67	20	3	.....	.....	IV Er	2933.82	1	.....	.....	.....	V E
2893.34	20	3	.....	.....	IV Er	2934.39	8	tr	.....	.....	V E
2893.47†	4n	2	.....	.....	IV	2934.62†	2	6	4	.....	III A
2894.59	8	12	10	2	III	2934.72†	20n	4	.....	.....	IV
2895.16†	4n	tr	.....	.....	V	2935.87†	15	10	10	8	I
2896.22	10	tr	.....	.....	V E	2937.73	15	15	15	10	I
2898.84	5	10	3	.....	III A	2938.30†	5n	1	.....	.....	IV
2899.19	20	15	8	4	II	2938.67†	6	8	8	3	II
2899.60	30	20r	10	6	II	2939.26†	2n	.....	.....	.....	V
2900.86*†	5N	1	.....	.....	IV	2941.11†	1	3	1	.....	III A
2903.09	10	tr	.....	.....	V E	2941.39†	10	1	.....	.....	IV E
2903.70	12	12	12	5	II	2941.50†	5	tr	.....	.....	IV E
2904.14	20	15	8	5	II	2942.02	tr	3	1	.....	III A
2905.62	1	.....	.....	.....	V E	2942.33*†	10	8?	8	6	I
2906.14	40r	20r	10	6	II	2942.39*†	10	8?	8	6	I
2906.48	20	2	.....	.....	IV Er	2943.19†	30r	15r	8	5	II
2907.47	15	1	.....	.....	IV E	2943.84†	12n	8	1	.....	IV
2908.83*	30	6	tr	.....	IV Er	2944.59	20	3	.....	.....	IV Er
2910.03	10	2	.....	.....	IV Er	2944.76	10n	8	1	.....	IV
2910.41*	5?	12	12	6	II A	2946.54	15	12	10	5	II
2911.09	10	2	.....	.....	IV Er	2949.09†	1	2	.....	.....	IV A
2914.30†	2n	1	.....	.....	IV	2949.15	1	.....	.....	.....	V E
2914.43†	2n	1	.....	.....	IV	2949.62	25	15r	8	6	II
2914.94*	50R	25r	15r	6	II	2949.91†	2n	tr	.....	.....	IV
2915.33*	10	12	12	6	II	2950.35	10	1	.....	.....	V E
2916.00	8	5	1	.....	IV	2951.84†	2n	3	.....	.....	IV
2917.34	4	.....	.....	.....	V E	2952.09	20	3	.....	.....	IV Er
2917.52	4	3	.....	.....	IV	2954.33	20	15	10	6	II
2917.94	8	5	1	.....	IV	2955.79	15	12	10	5	II
2919.98	6	12	10	2	III A	2956.12	1	5	1	.....	IV A

TABLE II—*Continued*

λ (I.A.)	Arc Int.	Furnace Intensities			Class	λ (I.A.)	Arc Int.	Furnace Intensities			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
2956.57†...	1n	....	....	....	V	3006.34....	6	5	tr	....	IV
2957.12....	8n	6	tr	....	IV	3006.90*†..	5N	2	....	....	IV
2957.30*...	10?	10?	8?	3	II	3008.61....	2	....	....	....	V E
2957.50....	10	tr	....	....	V E	3009.66†...	?N	1	....	....	IV
2959.99†...	2	2	....	....	IV	3010.84†...	?N	1	....	....	IV
2961.14....	10	8	2	....	III	3011.40†...	?N	2	....	....	IV
2962.07....	1	....	....	....	V	3011.58†...	1	tr	....	....	IV
2962.78....	30r	20r	15	10	II	3013.09....	4	....	....	....	V E
2963.83....	6	5	1	....	IV	3014.19†...	?	4	....	....	IV A
2968.29†...	5	10	1	....	IV A	3014.33....	15N	5	....	....	IV
2968.38....	8	....	....	....	V E	3014.82....	5	....	....	....	V E
2968.98....	3	3	....	....	IV	3014.92†...	1	6	1	....	IV A
2972.27....	3	....	....	....	V E	3016.17....	20	15	8	....	III
2974.23....	8	5	tr	....	IV	3016.36†...	1	2	....	....	IV A
2975.04....	8	5	tr	....	IV	3016.74....	5	....	....	....	V E
2975.64....	3	....	....	....	V E	3021.78....	6	6	1	....	IV
2976.17....	5	....	....	....	V E	3022.77†...	10N	4	....	....	IV
2976.51....	8	4	tr	....	IV E	3027.07....	2	tr	....	....	IV
2977.50....	25r	15r	20	15	I	3030.93*†..	5?	10?	6?	1	III A
2978.88....	4	3	....	....	IV	3031.00*†..	10?	8?	3?	....	III
2979.21†...	2	tr	....	....	IV	3033.43....	6	....	....	....	V E
2981.20....	1	....	....	....	V E	3033.75*†..	?	1	....	....	IV
2982.18....	2	2	....	....	IV	3033.80....	10	....	....	....	V E
2982.74*...	1	1	....	....	IV	3038.06†...	?N	1	....	....	IV
2988.01....	3	....	....	....	V E	3038.76....	10	6	1	....	IV
2989.58....	2	....	....	....	V E	3039.46†...	?N	1	....	....	IV
2990.31†...	1	1	....	....	IV	3040.13†...	1	1	....	....	IV
2990.93....	8	8	2	....	III	3041.40....	2	....	....	....	V E
2991.14†...	2	2	....	....	IV	3041.83....	8	6	tr	....	IV
2992.79†...	?N	tr	....	....	IV	3042.23....	3	tr	....	....	IV E
2994.01†...	1	2	....	....	IV A	3043.08*...	50r	25r	20	15	II
2994.50†...	1	1	....	....	IV	3043.51*...	50r	25r	20	15	II
2994.61*†..	2n	1	....	....	IV	3044.93....	50r	25r	20	15	II
2995.58....	4	5	1	....	IV	3047.21†...	?N	1	....	....	IV
2995.99....	3	tr	....	....	IV E	3048.17....	6	....	....	....	V E
2996.48....	6	6	1	....	IV	3048.83....	3	....	....	....	V E
2997.08†...	3N	1	....	....	IV	3050.33†...	1	1	....	....	IV
2997.87†...	5N	2	....	....	IV	3050.38....	25	12	2	....	IV
2998.62....	4	4	tr	....	IV	3050.88....	35r	20r	20	12	II
2999.20....	12	15	4	....	III	3051.39†...	tr	1	....	....	IV A
3000.59†...	tr	1	....	....	IV A	3052.19*...	20	20	20	12	II
3001.05†...	1n	1	....	....	IV	3053.37....	4	....	....	....	V E
3001.18....	7	....	....	....	V E	3053.65†...	80R	40R	30r	25	II
3001.90†...	10N	3	....	....	IV	3053.84....	2	....	....	....	V E
3002.44....	6	4	1	....	IV	3054.89†...	1	2	tr	....	IV A
3002.65....	8	8	3	....	III	3056.36*...	100R	50R	35r	25	II
3003.25....	5	6	....	....	IV	3056.59*†..	?	1	....	....	IV
3003.44....	2	....	....	....	V E	3060.45....	125R	60R	40r	25	II
3004.33....	4	8	1	....	IV A	3060.93*...	2	6	6	2	III A
3004.82....	10	12	2	....	IV	3062.71....	1	....	....	....	V E
3006.24†...	5N	3	....	....	IV	3063.25....	4	....	....	....	V E

TABLE II—*Continued*

λ (I.A.)	Arc Int.	Furnace Intensities High Temp.	Medium Temp.	Low Temp.	Class	λ (I.A.)	Arc Int.	Furnace Intensities High Temp.	Medium Temp.	Low Temp.	Class
3063.72	12	10	12	8	II	3102.29	40	15	5	.....	III Er
3065.62	1N	.....	.....	.....	V	3103.60†	1	1	.....	.....	IV
3066.38*	125R	60R	50r	35r	II	3103.99	6	6	1	.....	IV
3066.51*†	20	?	15	15	I	3104.92	1	.....	.....	.....	V E
3067.11	6	3	tr	.....	IV E	3106.12	5	5	1	.....	IV
3069.75	30r	20r	15	15	I	3107.12	5	5	1	.....	IV
3070.88†	2	5	2	.....	III A	3108.56†	N	1	.....	.....	IV
3072.73†	2n	2	.....	.....	IV	3108.68	2	.....	.....	.....	V E
3073.80*	60r	30r	20	20	II	3109.42†	1	1	.....	.....	IV
3074.06†	10n	3	.....	.....	IV	3110.71	30	10	4	.....	III Er
3074.83†	8n	2	.....	.....	IV	3110.9†	1	tr	.....	.....	IV
3075.28	10	8	2	.....	III	3112.13†	3	1	.....	.....	IV
3075.93	8	8	4	.....	III	3112.93	8	10	3	.....	III
3076.63†	4	3	1	.....	III	3113.56	2	.....	.....	.....	V E
3076.69†	5n	1	.....	.....	IV	3116.35†	1	tr	.....	.....	IV
3077.73	6	2	.....	.....	IV	3118.39	30	10	4	.....	III Er
3077.86†	5n	1	.....	.....	IV	3120.75	3	.....	.....	.....	V E
3079.35	4	8	4	.....	III A	3121.17	20	4	tr	.....	IV E
3080.16	6	10	6	2	III	3121.78	4	8	2	.....	III A
3080.34	12	6	2	.....	III	3122.92	2	.....	.....	.....	V E
3081.28	1	.....	.....	.....	V E	3123.25†	1	.....	.....	.....	V
3081.31†	1	1	.....	.....	IV	3125.29	40	15	3	.....	III Er
3081.96†	6	6	1	.....	IV	3126.19	25	6	1	.....	III Er
3082.08	50r	25r	20	15	II	3130.26	25	6	1	.....	III Er
3082.56	1	.....	.....	.....	V E	3131.3†	1	tr	.....	.....	IV
3083.21	1	.....	.....	.....	V E	3131.9†	1N	tr	.....	.....	IV
3083.50	30	15	6	1	III	3133.0†	1N	tr	.....	.....	IV
3084.38	20	10	5	1	III	3133.31	20	5	1	.....	III E
3085.84†	1n	1	.....	.....	IV	3134.54†	1	tr	.....	.....	IV
3086.50	1	.....	.....	.....	V E	3134.91	4	.....	.....	.....	V E
3087.07	15	10	3	tr	III	3135.17†	2	2	.....	.....	IV
3087.49	2n	1	.....	.....	IV	3136.48	4	tr	.....	.....	V E
3088.10	30	15	6	1	III	3138.50	3	2	.....	.....	IV
3089.12	25	12	4	tr	III	3139.04	3	1	.....	.....	IV
3090.40*†	?	1	.....	.....	IV	3139.70	4	.....	.....	.....	V E
3090.54†	3n	2	tr	.....	III	3139.97	4	3	tr	.....	IV
3090.81	4	10	5	1	III A	3141.44	1	.....	.....	.....	V E
3091.42†	20	15	15	10	II	3142.45	8	.....	.....	.....	V E
3091.52†	15	10	10	5	II	3143.2†	1	tr	.....	.....	IV
3092.72*	8	3	3	1	III	3145.32*	10	1?	.....	.....	IV E
3092.85†	1	1	.....	.....	IV	3145.65†	?N	1	.....	.....	IV
3093.14	50	20	12	.....	III Er	3145.95	5	tr	.....	.....	V E
3093.24*†	6?	10	7	1	III	3146.29*	4	2	tr	.....	IV
3093.79	25	12	7	tr	III	3146.8†	1N	tr	.....	.....	IV
3094.21	6	.....	.....	.....	V E	3147.26	8	5	tr	.....	IV
3094.70	20	10	5	tr	III	3147.97†	3N	1	.....	.....	IV
3095.90	5	5	1	.....	III	3150.03†	2N	1	.....	.....	IV
3096.04†	2	tr	.....	.....	IV	3150.59	5	4	tr	.....	IV
3099.59†	2n	1	.....	.....	IV	3151.32	2	.....	.....	.....	V E
3100.93	5	.....	.....	.....	V E	3152.75†	2N	1	.....	.....	IV
3101.4†	1	1	.....	.....	IV	3153.54†	5N	3	tr	.....	IV

TABLE II—*Continued*

λ (I.A.)	Arc Int.	Furnace Intensities: High Temp.	Furnace Intensities: Medium Temp.	Furnace Intensities: Low Temp.	Class	λ (I.A.)	Arc Int.	Furnace Intensities: High Temp.	Furnace Intensities: Medium Temp.	Furnace Intensities: Low Temp.	Class
3155.37....	2	.....	.....	.....	V E	3168.12....	5	.....	.....	.....	V E
3156.19....	10	5	1	.....	IV	3169.6†....	1	1	.....	.....	IV
3156.89†...	2n	2	.....	.....	IV	3177.83†...	1	1	.....	.....	IV
3158.77†...	?n	1	.....	.....	IV	3180.09....	1	1	.....	.....	IV
3159.87....	2	.....	.....	.....	V	3180.56....	1	1	.....	.....	IV
3161.9†....	3N	1	.....	.....	IV	3181.63†...	1	1	.....	.....	IV
3162.73....	1	.....	.....	.....	V E	3182.76†...	1	1	.....	.....	IV
3163.02....	1	.....	.....	.....	V E	3183.40....	150R	75R	75r	40r	II
3163.89....	4	2	tr	.....	IV	3183.96*†.	300R	150R	150R	40r	II
3164.5†....	1	tr	.....	.....	IV	3184.00*†.				50r	II
3164.83....	5	.....	.....	.....	V E	3185.38....	200R	100R	100r	60r	II
3165.59....	3	2	.....	.....	IV						

λ	
2406.7	Blend *Fe* in arc.
2507.85	Double.
2521.56	Probably double.
2637.15	Probably double.
2678.55	Blend in arc with enhanced line.
2747.50	Blend in arc with enhanced line.
2755.64	Enhanced line on red side.
2770.94	Probably double.
2777.70	Coincides with enhanced line.
2851.79	Blend *Fe*. Furnace line probably all *V*.
2879.15	Double. Red component strongest.
2900.86	Furnace line at violet edge of diffuse arc line.
2908.83	Double. Violet component strongest.
2910.41	Coincides with enhanced line of same intensity in spark as λ 2911.09.
2914.94	Enhanced line on violet side.
2915.33	Similar to λ 2910.41
2942.33, 2942.39	Not resolved at high temperature. Measured in low-temperature furnace.
2957.30	Blend *Fe*. Probable intensity *Fe* line subtracted.
2982.74	Blend in arc with enhanced line.
2994.61	Blend in arc with enhanced line.
3006.90	Furnace line at violet edge of arc line.
3030.93, 3031.00	Not fully resolved.
3033.75	Blend in arc with following line.
3043.08	Measures λ 3043.12 in low-temperature furnace.
3043.51	Measures λ 3043.55 in low-temperature furnace. Strength in spark indicates blend with enhanced line.
3052.19	Probably unresolved doublet. Components of about equal intensity.
3056.36	Measures λ 3056.32 in low-temperature furnace.

λ	
3056.59	Blend in arc with preceding line.
3060.93	Measures λ 3060.91 in low-temperature furnace.
3066.38	Measures λ 3066.36 in low-temperature furnace.
3066.51	Blend with preceding line at high temperature.
3073.80	Red side of reversal strongest, as if double. Sharp line in low-temperature furnace, measures λ 3073.82.
3090.40	Very faint in arc. Close to following line.
3092.72	Measures λ 3092.70 in low-temperature furnace.
3093.24	Blend in arc with preceding line.
3145.32	Faint furnace line to violet of enhanced line.
3146.29	Faint enhanced line to violet in arc.
3183.96 3184.00	Measured with incomplete resolution as sharp impurity lines in low-temperature spectrum of titanium.

columns. A line distinctly outlined in the negative is given the intensity "1," a fainter appearance being indicated as "trace" ("tr"); "n" and "N" denote degrees of diffuseness in the structure of arc lines, while "r" and "R" indicate partial and complete self-reversal, respectively. Cases of extreme diffuseness, difficult blends, or disturbance by the cyanogen bands have their intensities questioned, and are usually noted in the remarks after Tables II and IV.

Classes.—In the final column, the classes are assigned according to the usual method. Lines in Classes I and II appear at low temperature and are conspicuous in the absorption spectrum. In the ultra-violet, the distinction between these two classes is difficult and may not always be significant. The Class I lines are usually not strong at high temperature or in the arc and maintain their strength at low temperature to a greater degree than those of Class II. Lines are not usually placed in Class I unless a low-temperature spectrum is available, but exception is made for a group of chromium lines, λ 2678–λ 2703, whose strength in the absorption furnace as compared with the arc is noteworthy. Lines of Class III are usually well developed at medium temperature, while lines belonging distinctly to high temperature are placed in Classes IV and V, those of Class V being absent or very faint in the furnace spectrum.

The letter "A" after the class number designates lines relatively stronger in the furnace than in the arc. Enhanced lines, selected from spark spectra having the same scale as those of arc and furnace, are distinguished by "E" following the class number. If the

TABLE III

Chromium Lines in Arc and Absorption Furnace

λ (I.A.)	Arc	Absorption Furnace	Class	λ (I.A.)	Arc	Absorption Furnace	Class
2362.22....	6	1	III	2549.51....	12	10	II
2364.74....	20n	15	II	2553.06....	6	3	II
2365.96....	12n	10	II	2557.15....	10	7	II
2366.85....	15n	10	II	2560.71....	12	8	II
2370.41....	10	2	III	2566.56....	4	3	II
2373.72....	15	3	III	2568.09*...	4	3	II
2378.02*...	10	1	III	2568.53*...	3	2	II
2379.92*...	10	1	III	2571.76....	15	6	II
2383.29....	20	5	III	2572.14....	7	3	II
2385.72†...	4n	1	III	2577.66....	10	5	II
2386.17†...	4	1	III	2578.27....	2	....	V
2389.42....	5	1	III	2579.16....	6	2	II
2392.88....	8	1	III	2583.04....	2	....	V
2395.78....	5	1	III	2584.64....	5	2	II
2396.37....	10	1	III	2588.21....	6	3	II
2399.06....	8	1	III	2591.87....	15	8	II
2399.57....	7	1	III	2603.57....	5	2	II
2408.66....	15	10	III	2608.41....	2	1	II
2408.75....	10		III	2610.31....	2	1	II
2474.08....	8	1	III	2612.04....	3	1	II
2479.16....	6	....	V	2612.21....	3	1	II
2491.34....	10	4	II	2613.32....	3	1	II
2492.55....	15	5	II	2618.28*...	10	2	III
2495.06....	7	3	II	2619.49....	3	tr	III
2496.31....	20	8	II	2620.00....	4	tr	III
2499.86....	5	3	II	2620.47....	6	1	III
2500.66....	3	1	II	2620.85....	3	tr	III
2502.55....	15	3	III	2622.87....	8	2	III
2504.31....	15	8	II	2625.35....	6	1	III
2507.34....	4	....	V	2626.58....	6	1	III
2508.12....	8	3	II	2629.82....	5	tr	III
2508.99....	8	3	II	2638.88....	3	....	V
2510.61*...	5	3?	II	2639.45*...	2	....	V
	5	3?	II	2642.13....	6	....	V
2511.98....	5	....	V	2653.57....	15	....	V E
2513.62....	7	2	II	2658.60....	15	....	V E
2516.90....	10	4	II	2661.74....	5	....	V E
2517.56....	5	2	II	2663.41....	15	....	V E
2517.87....	5	2	II	2663.68....	6	....	V E
2518.06....	3	1	II	2666.02....	15	....	V E
2518.71....	8	3	II	2668.71....	15	....	V E
2519.52....	15	10	II	2669.39....	4	1	III
2527.11....	10	4	II	2671.80....	15	....	V E
2528.02....	6	3	II	2672.00....	5	3	II
2528.23....	4	2	II	2672.83....	12	....	V E
2529.14....	3	2	II	2673.65....	3	2	II
2530.45....	7	4	II	2677.14....	25	....	V E
2534.32....	4	....	V	2678.14....	6	5	I
2541.37....	12	5	II	2678.75....	15	....	V E
2541.66....	4	2	II	2680.29....	4	3	I
2545.21....	3	1	II	2681.41....	3	1	II
2545.64....	6	2	II	2687.07....	10	....	V E

TABLE III—*Continued*

λ (I.A.)	Arc	Absorption Furnace	Class	λ (I.A.)	Arc	Absorption Furnace	Class
2688.03....	8	6	I	2742.02....	12	....	V E
2690.26....	5	4	I	2742.15....	10	....	V
2691.06....	12	....	V E	2743.11....	12	....	V E
2696.55....	3	3	I	2748.26....	50	30	II
2697.90....	1	....	V E	2748.99....	15	....	V E
2698.40....	10	....	V E	2750.75....	15	....	V E
2698.67....	10	....	V E	2751.60....	6	6	I
2700.58....	4	3	I	2751.89....	12	....	V E
2701.95....	12	6	II	2752.87....	60	25	II
2702.50....	3	....	V	2754.90....	3	....	V
2703.47*...	5	4	I	2755.28....	4	....	V
2703.75....	3	....	V E	2756.76....	3	....	V
2704.73....	3	....	V	2757.12....	60	20	II
2705.40....	4	....	V	2757.73....	12	....	V E
2705.70....	3	2	II	2759.40....	2	....	V
2710.2.....	10n	....	V	2761.75....	50	20	II
2712.30....	12	....	V E	2762.61....	25	....	V E
2716.15....	6	4	II	2763.07....	6	....	V
2717.45....	4	....	V E	2764.39....	50	25	II
2722.75....	10	....	V E	2766.56....	30	....	V E
2726.49....	80	40	II	2767.54....	5	....	V
2727.26....	2	....	V E	2769.91....	100	50	II
2731.90....	60	30	II	2771.46....	4	....	V
2736.43....	60	20	II	2775.70....	4	....	V
2737.27*...	3	5?	II?	2777.68....	5	....	V
2739.37....	10	....	V	2778.10....	6	....	V E
2740.10....	7	....	V E	2780.73....	150	60	II
2741.07....	10	....	V				

enhanced line reverses in the condensed spark, this is denoted by "Er," while "u" is added if the reversal is unsymmetrical.

In the use of this material, as close regard as possible should be paid to the intensities themselves, in addition to the class assigned. Faint lines may in some cases be placed in too high a class owing to their failure to appear in the lower-temperature spectrograms, which usually have less general intensity.

DISCUSSION

Low-temperature lines.—On account of their importance in the search for regularities in the spectrum, it may be worth while to call attention to certain groups of lines which are prominent in the absorption furnace. As a rule they are strong arc lines, and belong usually in Class II.

TABLE IV

TEMPERATURE CLASSIFICATION OF CHROMIUM LINES

λ (I.A.)	Arc Int.	Furnace Intensities			Class	λ (I.A.)	Arc Int.	Furnace Intensities			Class
		High Temp.	Medium Temp.	Low Temp.				High Temp.	Medium Temp.	Low Temp.	
2835.64....	40	2	.....	.....	V Er	2921.81....	3	.....	.....	.....	V E
2843.24....	35	2	.....	.....	V Er	2925.58†...	8n	1n	.....	.....	IV
2845.99....	5	tr	.....	.....	V	2928.14....	3	.....	.....	.....	V E
2849.29....	4	tr	.....	.....	V	2928.25....	3	.....	.....	.....	V E
2849.83....	30	1	.....	.....	V Er	2929.59....	12n	2	tr	.....	IV
2855.68....	25	1	.....	.....	V Er	2932.5†....	4n	.....	.....	.....	IV
2858.90....	20	1	.....	.....	V E	2933.43†...	8n	2	tr	.....	IV
2860.94....	15	1	.....	.....	V E	2933.96....	2	.....	.....	.....	V E
2862.59....	20	1	.....	.....	V E	2934.49....	15n	..2..	.....	.....	IV
2865.10....	20	tr	.....	.....	V E	2935.13....	3	.....	.....	.....	V E
2866.76....	15	tr	.....	.....	V E	2935.54....	3	.....	.....	.....	V
2867.64....	15	tr	.....	.....	V E	2938.85†...	15n	4n	1n	.....	III
2870.04†...	8n	1	.....	.....	IV	2940.33†...	12n	2	tr	.....	IV
2870.17†...	4	1	.....	.....	IV	2941.89*...	3	6	3	1	II A
2870.43....	6	.....	.....	.....	V E	2946.82....	1	.....	.....	.....	V E
2871.64....	12	6	3	2	II	2948.85....	12n	3n	1n	.....	III
2873.21....	7	2	.....	.....	IV	2956.29....	8	8	4	3	II
2873.49....	12	.....	.....	.....	V E	2957.2*†...	10n	?	.....	.....	V
2873.82....	4	.....	.....	.....	V E	2959.04....	2	.....	.....	.....	V
2875.98....	10	.....	.....	.....	V E	2962.38....	2	.....	.....	.....	V
2876.24....	10	.....	.....	.....	V E	2963.68....	8n	2	1	.....	III
2877.97....	7	.....	.....	.....	V E	2967.67....	20r	15r	10r	10	I
2879.28....	15	8	3	2	II	2968.18†...	5n	1n	.....	.....	IV
2880.89....	5	.....	.....	.....	V E	2968.98....	1	5	3	2	II A
2881.15....	5	2	.....	.....	IV	2971.10....	30r	20r	15r	12	II
2886.99....	15	12	3	2	II	2971.90....	6	.....	.....	.....	V E
2888.38....	2	5	2	.....	III A	2975.43....	25r	18R	12r	12	II
2889.22*†..	15	6?	2?	1?	II	2979.73....	5	.....	.....	.....	V E
2889.29*†..	8	5?	2?	1?	II	2980.80....	20r	15r	10r	8	II
2890.19....	4	1	.....	.....	IV	2984.03....	4	1	.....	.....	IV
2890.76....	4	1	.....	.....	IV	2984.84*†..	6?	6?	4?	4?	I?
2891.42....	8	2	.....	.....	IV	2985.32....	4	.....	.....	.....	V E
2893.26....	20r	15r	4	2	II	2985.85....	30R	20r	15r	12	II
2894.09....	12	8	3	2	II	2985.98....	60R	50R	30R	25r	II
2896.75....	15	10	4	2	II	2986.10*...	10	8	8	8	I?
2899.23....	10	7	4	2	II	2986.49....	100R	80R	60R	30r	II
2900.27....	2	4	2	1	II A	2988.60....	75r	40R	20r	15	II
2902.46....	1	2	1	.....	III A	2989.16....	4	.....	.....	.....	V E
2904.70....	5	1	tr	.....	IV	2991.89....	25r	15r	12r	10	II
2905.50....	15	10	3	2	II	2994.03....	15	12	10	7	II
2909.05....	20	12	5	3	II	2995.09....	30r	20r	15r	12	II
2910.91....	20	12	5	3	II	2996.58....	40r	30R	20r	15	II
2911.18....	15	10	5	3	II	2998.10....	4	.....	.....	.....	V
2913.73....	10	2	tr	.....	IV	2998.79....	30r	20r	15r	10	II
2916.16....	4	6	2	1	II	3000.89*...	40r	30R	25R	20r	II
2917.09†...	6n	.....	.....	.....	V	3003.73....	3	.....	.....	.....	V
2917.50†...	3n	.....	.....	.....	V	3005.07....	35r	25R	20r	12	II
2919.42†...	2n	.....	.....	.....	V	3011.08....	3	.....	.....	.....	V
2921.36*...	4	.....	.....	.....	V	3013.00....	15	12	10	10	I

TABLE IV—*Continued*

λ (I.A.)	Arc Int.	Furnace Intensities High Temp.	Medium Temp.	Low Temp.	Class	λ (I.A.)	Arc Int.	Furnace Intensities High Temp.	Medium Temp.	Low Temp.	Class
3013.68	40R	30R	20r	15	II	3110.78†	3n	....	....	....	V
3014.78	50R	40R	30R	25r	II	3110.89	8	3	1	....	III
3014.92	75R	60R	40R	30r	II	3110.99†	4n	....	....	....	V
3015.17	30r	25R	20r	15	II	3111.34	2n	....	....	....	V
3017.50	100R	80R	60R	40R	II	3111.94†	1n	....	....	....	V
3018.45	40R	30R	20r	15	II	3112.98	2	....	....	....	V
3018.80	25r	20r	15r	12	II	3113.72†	2n	....	....	....	V
3020.64*	50R	40R	30R	20r	II	3114.10†	4n	....	....	....	V
3021.56	100R	80R	60R	40R	II	3114.44	2	....	....	....	V
3024.35	70R	50R	35R	25r	II	3114.85	4	....	....	....	V
3024.64	4	1	tr	....	IV	3118.65	15	....	....	....	V E
3029.18	20	15	12	10	II	3119.19	10	5	2	....	III
3030.26	60R	40R	30R	20r	II	3119.68	8	4	1	....	III
3031.34	12	10	10	10	I	3120.38	15	....	....	....	V E
3031.43	5	1	....	....	IV	3120.70	5	2	tr	....	IV
3032.87	2	....	....	....	V E	3121.63	6n	1	....	....	IV
3034.15	40r	20r	15r	12	II	3124.98	20	....	....	....	V
3037.00*	40r	30R	20r	15	II	3125.85	3	1	....	....	IV
3039.75	15	12	10	10	I	3127.53	3n	tr	....	....	IV
3040.87*	50r	35R	25r	15	II	3128.60	8	....	....	....	V E
3047.44	6	1	tr	....	IV	3131.17	6	4	2	....	III
3049.80	4	5	4	2	II	3132.06	20	....	....	....	V E
3050.11	5	....	....	....	V E	3132.82	6	3	1	....	III
3052.18	8	1	tr	....	IV	3134.92	4	1	....	....	IV
3053.88	125R	50R	30R	20r	II	3135.87	4	1	....	....	IV
3061.68	6	2	1	....	III	3136.64	8	....	....	....	V E
3061.81	3	tr	....	....	IV	3138.18	4	1	....	....	IV
3065.05	10	3	1	....	III	3141.83	4	1	....	....	IV
3071.30	4	2	tr	....	IV	3143.67	3n	1	....	....	IV
3073.68	12	4	2	....	III	3144.39	15n	5n	3n	....	III
3076.17	2	tr	....	....	IV	3145.57	5	....	....	....	V
3076.54	2	1	....	....	IV	3147.18	12	....	....	....	V E
3077.79	10	3	1	....	III	3148.40	15	8	5	1	III
3080.72	2	....	....	....	V	3152.88	6	2	1	....	III
3084.53	2	tr	....	....	IV	3153.52	5	1	....	....	IV
3086.74	2	1	....	....	IV	3154.7†	5n	tr	....	....	IV
3087.49	3	1	tr	....	IV	3155.14	15	10	7	1	III
3094.28	1n	....	....	....	V	3159.57	20n	8n	5n	tr	III
3095.34	6	1	tr	....	IV	3163.74	20	12	8	1	III
3095.81	12n	5	3	....	III	3169.54	3	tr	....	....	IV
3096.03	1	....	....	....	V E	3179.22	10n	4n	2n	....	III
3096.48	6n	3	1	....	III	3180.69*	20	2	1	....	III
3096.65	2	tr	....	....	IV	3181.41	4	....	....	....	V E
3099.44	1	tr	....	....	IV	3187.98	25n	8n	5n	tr	III
3104.68	3	tr	....	....	IV	3192.10	5	10	10	5	II A
3105.54	2	....	....	....	V	3197.07	10	....	....	....	V E
3105.83	1n	....	....	....	V	3198.06	8	3	1	....	III
3107.23	2n	....	....	....	V	3208.51	3	....	....	....	V E
3108.9†	2n	....	....	....	V	3209.16	12	....	....	....	V E
3109.29	10	4	1	....	III	3211.25	6	2	1	....	III
3109.7†	4n	....	....	....	V	3217.35	8	....	....	....	V E

TABLE IV—*Continued*

λ (I.A.)	Arc Int.	Furnace Intensities High Temp.	Furnace Intensities Medium Temp.	Furnace Intensities Low Temp.	Class	λ (I.A.)	Arc Int.	Furnace Intensities High Temp.	Furnace Intensities Medium Temp.	Furnace Intensities Low Temp.	Class
3218.13....	1n	....	....	....	V	3313.70....	2	1	tr	....	III
3218.67....	10n	3n	1n	....	III	3314.16....	1	tr	....	....	IV
3219.57....	8	2	1	....	III	3314.48....	1	....	....	....	V
3226.54....	3	10	10	6	II A	3315.16....	1	....	....	....	V
3229.18....	8	2	tr	....	IV	3316.16....	1	....	....	....	V
3233.26....	5	15	15	8	II A	3316.47....	3	....	....	....	V
3235.12....	1	....	....	....	V	3318.1.....	8N	....	....	....	V
3237.25....	1	....	....	....	V	3321.19....	2	1	tr	....	III
3237.69....	10	5	4	tr	III	3323.24....	1	3	tr	....	III A
3238.08....	5	2	1	....	III	3324.06....	3	....	....	....	V
3238.48....	2	tr	....	....	IV	3324.36....	1	....	....	....	V
3240.93....	6	15	12	8	II A	3326.59....	10	5	3	tr	III
3244.10†...	7	15	12	10	I A	3327.23....	2n	tr	....	....	IV
3245.46†...	5	10	10	12	I A	3328.36....	2	....	....	....	V E
3245.53†...	8	3	2	....	III	3329.07....	8	4	2	tr	III
3247.27....	5	12	12	10	I A	3330.61....	3n	1n	....	....	IV
3251.56....	4	tr	....	....	IV	3332.89....	6	3	1	....	III
3251.84....	15	8	5	2	II	3333.61....	20n	8	5	1	III
3253.26....	2	1	....	....	IV	3334.71....	30n	12	8	2	III
3254.91....	8n	....	....	....	V	3334.91....	4	2	1	....	III
3257.81....	20	8	5	2	II	3336.34....	4	....	....	....	V E
3259.69....	2	6	5	3	II A	3336.95....	2	....	....	....	V
3259.96....	20	8	4	2	II	3337.21....	1	....	....	....	V
3262.81....	1	....	....	....	V	3339.76....	7	....	....	....	V E
3266.59....	5	15	15	8	II A	3341.41....	3n	....	....	....	V
3267.02....	1	....	....	....	V	3342.56....	3	....	....	....	V E
3270.08....	1	....	....	....	V E	3343.20†...	3	1	1	....	III
3270.67....	2	....	....	....	V	3343.30†...	6	3	2	tr	III
3271.91....	3n	....	....	....	V	3343.72*†.	5n	3	2	....	III
3275.73....	1	....	....	....	V	3344.47....	3	1	tr	....	III
3277.81....	3	....	....	....	V	3345.10....	3	1	tr	....	III
3284.81....	1n	....	....	....	V	3345.32....	2	tr	....	....	IV
3286.29....	4	2	1	....	III	3345.96†...	8	5	4	1	III
3287.7.....	8N	....	....	....	V	3346.09†...	8n	3	2	tr	III
3291.0†....	3N	....	....	....	V	3346.66†...	8	4	4	1	III
3293.77*...	10N	....	....	....	V	3346.74....	6	3	3	1	III
3295.38....	2	....	....	....	V E	3347.42....	2	tr	....	....	IV
3296.81....	1n	....	....	....	V	3347.77....	6	....	....	....	V E
3297.28....	3n	....	....	....	V	3348.99....	15n	6	5	1	III
3298.26....	5	2	1	....	III	3349.27....	6	3	2	tr	III
3300.76....	1	....	....	....	V	3351.51†...	5n	1	tr	....	III
3302.16....	6n	1n	....	....	IV	3351.61†...	5	2	1	....	III
3302.82....	4	2	1	....	III	3351.96*...	10	20	20	20	I A
3304.33....	1	....	....	....	V	3353.05....	3	1	tr	....	III
3305.16....	1	....	....	....	V	3353.60....	2	tr	....	....	IV
3307.69....	8	4	3	1	II	3356.39....	4n	....	....	....	V
3309.80....	2	1	tr	....	III	3356.73....	4n	....	....	....	V
3311.27....	1	....	....	....	V	3357.41....	1	....	....	....	V
3312.06....	2	1	tr	....	III	3358.54....	8	....	....	....	V E
3312.69....	1	....	....	....	V	3359.20....	1	tr	....	....	IV
3313.01*...	2	1	?	....	III ?	3360.15†...	1	tr	....	....	IV

TABLE IV—*Continued*

λ (I.A.)	Arc Int.	Furnace Intensities: High Temp.	Furnace Intensities: Medium Temp.	Furnace Intensities: Low Temp.	Class
3360.31	6	....	....	....	V E
3361.75	1	....	....	....	V
3362.26*	20n	8	8	3	II
3362.73	5n	4	3	1	II
3365.55	2	1	tr	....	III
3367.56*	20n	12	8	3	II
3368.07	20	....	....	....	V E
3370.26	10n	2	....	....	IV
3374.61	3	3	1	....	III
3374.96	2	1	tr	....	III
3375.63†	2n	....	....	....	V
3376.18†	6n	....	....	....	V
3376.42	6	1	....	....	IV
3378.36	2	....	....	....	V E
3379.18*	10	20	20	20	I A
3379.36	2	....	....	....	V E
3379.55*†	5n	4	2	tr	III
3379.85*	10n	6	4	1	III
3382.07	2	1	....	....	IV
3382.68	8	....	....	....	V E
3384.26	4	3	1	tr	III
3384.66	8	5	3	1	III
3385.32	6	1	tr	....	III
3386.51	5	1	tr	....	III
3388.68	8	6	4	1	III
3390.79	5	1	....	....	IV
3391.11†	1	1	tr	....	III
3391.41*	6	1	....	....	IV
3393.03	3	....	....	....	V E
3393.84	4	....	....	....	V E
3394.31	4	....	....	....	V E
3402.39	3	....	....	....	V E
3403.31	15	....	....	....	V E
3403.62	10	1	tr	....	IV
3404.03†	1	tr	....	....	IV
3406.92†	2n	....	....	....	V
3407.26	12n	2n	tr	....	IV
3408.04	8n	1n	tr	....	IV
3408.76	15	....	....	....	V E
3409.36	10n	2n	tr	....	IV
3411.04	12n	2n	tr	....	IV
3414.29*†	1n	....	....	....	V
3415.58†	2n	....	....	....	V
3418.00†	1n	....	....	....	V
3419.67†	1n	....	....	....	V
3419.89†	2n	tr	....	....	IV
3421.21	10	....	....	....	V E
3421.72	1	....	....	....	V
3422.74	15	....	....	....	V E
3425.99	2	2	1	....	III
3427.66	2n	tr	....	....	IV
3431.27	6	6	4	1	III
3431.57†	2	2	2	....	III
3431.67†	4	3	2	....	III
3431.96	5	5	3	tr	III
3432.30	5	5	3	tr	III
3432.82	2	....	....	....	V
3433.29	7	....	....	....	V E
3433.60	25	25	20	15	II
3433.85†	2n	1	....	....	IV
3434.09	7	8	6	3	II
3435.46	2	1	1	....	III
3435.67	6	5	5	2	II
3435.81*	6	5	4	2	II
3436.17	20	20	15	8	II
3439.35	2	tr	....	....	IV
3441.11	6	8	5	3	II
3441.45	20	20	15	8	II
3443.83†	5	2	1	....	III
3445.61	20	20	15	8	II
3447.01	8	8	5	2	II
3447.43	20	15	12	8	II
3447.75	12	10	8	3	II
3448.19	2	1	1	....	III
3450.85	2	....	....	....	V
3453.35	20	15	15	8	II
3453.75	8	6	5	2	II
3454.79†	1	1	tr	....	III
3455.26	6	5	4	2	II
3455.60	20	20	15	7	II
3456.60†	1	1	tr	....	III
3457.90†	1	tr	....	....	IV
3458.07	5	1	....	....	IV
3460.41	12	5	4	1	III
3463.70	2	....	....	....	V
3464.84	4	3	2	1	II
3465.07†	1	tr	....	....	IV
3465.22	12	8	8	3	II
3465.58	4	3	2	1	II
3467.00	10	2	1	....	III
3467.69	12	6	4	2	II
3468.73	4	tr	....	....	IV
3469.57	10	4	2	tr	III
3470.40	8	5	4	tr	III
3470.50	5	3	2	tr	III
3471.50	4	3	2	....	III
3472.77	8	6	4	tr	III
3472.87	7	4	2	tr	III
3473.61	8	8	4	1	III
3474.38	7	5	2	tr	III
3474.85	5	2	1	....	III
3475.11	2	tr	....	....	IV

TABLE IV—*Continued*

λ (I.A.)	Arc Int.	Furnace Intensities: High Temp.	Furnace Intensities: Medium Temp.	Furnace Intensities: Low Temp.	Class
3476.17†	2	.....	.....	.....	V
3477.16	4	2	1	.....	III
3477.24†	2	tr	.....	.....	IV
3478.76	5	3	1	.....	III
3479.10	3	1	tr	.....	III
3479.30	5n	.....	.....	.....	V
3480.30	3	2	1	.....	III
3481.31	20	10	8	4	II
3481.56	15	6	4	1	III
3483.51	2	tr	.....	.....	IV
3484.16	3	.....	.....	.....	V E
3486.48	3	.....	.....	.....	V
3488.41	8	3	1	.....	III
3494.96	12	5	2	.....	III
3495.37	6	.....	.....	.....	V E
3495.96†	5	1	.....	.....	IV
3501.45	2	tr	.....	.....	IV
3501.75	1	.....	.....	.....	V
3502.30	5	4	2	.....	III
3503.88†	1n	tr	.....	.....	IV
3507.21†	4n	1n	.....	.....	IV
3508.10	5	2	tr	.....	III
3508.85	8n	4	1	.....	III
3510.34*†	10N	4	2	.....	III
3510.53	12	6	3	.....	III
3511.81	6	.....	.....	.....	V E
3512.67†	3n	3	1	.....	III
3517.18	1	1	.....	.....	IV
3518.38	2	tr	.....	.....	IV
3519.5	1n	.....	.....	.....	V
3519.7	4n	4	1	.....	III
3522.8*†	3n	1	.....	.....	IV
3522.95†	3	1	.....	.....	IV
3523.60	3	1	.....	.....	IV
3525.5†	8N	1	.....	.....	IV
3527.07	8n	4	2	.....	III
3531.08	2	.....	.....	.....	V
3532.5†	5N	1	.....	.....	IV
3532.90†	5	.....	.....	.....	V
3536.49*†	3n	?	?	.....	IV ?
3536.77*†	6n	?	?	.....	IV ?
3537.23*	5	1 ?	tr ?	.....	IV ?
3545.8*†	1n	?	.....	.....	IV ?
3546.4†	1n	.....	.....	.....	V
3547.98†	8n	5	2	.....	III
3548.73†	1n	.....	.....	.....	V
3548.97†	2n	1	.....	.....	IV
3549.29†	6n	4	1	.....	III
3550.66	15	.....	.....	.....	V
3552.97*†	8n	2	.....	.....	IV
3553.97†	2	.....	.....	.....	V
3555.75	3	.....	.....	.....	V
3556.12	3	.....	.....	.....	V
3558.51	30	10	2	.....	III
3559.22*†	5n	?	.....	.....	IV ?
3559.80*	3	?	.....	.....	IV ?
3560.6*†	2n	?	.....	.....	IV ?
3560.9†	2n	.....	.....	.....	V
3562.26	2	.....	.....	.....	V
3562.48	1	.....	.....	.....	V
3562.91	2	.....	.....	.....	V
3563.79†	1n	.....	.....	.....	V
3564.27	1	.....	.....	.....	V
3564.72	3	2	.....	.....	IV
3564.96†	2	1	.....	.....	IV
3565.16†	2	1	.....	.....	IV
3566.13	40	8	2	.....	III
3568.42*†	2n	1 ?	.....	.....	IV ?
3568.99*†	2n	?	.....	.....	IV ?
3569.30†	2n	.....	.....	.....	V
3571.65†	1n	.....	.....	.....	V
3572.44†	1n	.....	.....	.....	V
3572.75	5	3	tr	.....	IV
3573.65	10	4	2	.....	III
3574.04	7	4	2	.....	III
3574.40†	15n	4	2	.....	III
3574.80†	8	3	2	.....	III
3574.94†	4	2	1	.....	III

λ	
2378.02	Double.
2379.92	Double.
2510.61	Double, partially resolved.
2568.09	Double, red component strongest.
2568.53	Double, violet component strongest.
2618.28	Double.
2639.45	Double, violet component strongest.

λ	
2703.47	Enhanced line on red side.
2737.27	Furnace line probably largely *Fe*.
2889.22 2889.29	Not resolved in furnace.
2921.36	Close to enhanced line.
2941.89	Close to enhanced line.
2957.2	*Fe* line on red side.
2984.84	Coincides with *Fe* λ 2984.83.
2986.10	Close to preceding strong line and difficult.
3000.89	*Fe* line on red side.
3020.64	Blend *Fe*.
3037.00	More widely reversed in arc than λ 3034.15.
3040.87	Enhanced line on red side.
3180.69	Probable blend with enhanced line in arc.
3293.77	Sharp line of class V superposed.
3313.01	Superposed on diffuse arc line which shows faintly in furnace.
3343.72	Line has strong center, possibly a superposed sharp line.
3351.96	Very strong in absorption. Compare λ 3379.18.
3362.26	Unusual type of diffuse line.
3367.56	Compare λ 3362.26.
3379.18	Very strong in absorption. Compare λ 3351.96.
3379.55	Furnace line may be due to impurity.
3379.85	Blend in arc with enhanced line.
3391.41	Enhanced line on red side.
3414.29	Probably double.
3435.81	Probably double.
3510.34	Arc line made up of three unresolved lines, central line sharp in furnace.
3522.8	Structure resembles λ 3510.34.
3536.49 3536.77	Disturbed by band lines.
3537.23	Furnace line may be band line.
3545.8	Coincides with band line.
3552.97	Arc line superposed on hazy patch, probably made up of three nebulous lines. Furnace line may be band line.
3559.22 3559.80 3560.6 3568.42 3568.99	Disturbed by band lines.

For vanadium, the first of these groups extends from λ 2400 to λ 2442. This region is very difficult for the furnace, and the intensities are low, resulting in the lines being placed in Class III. Succeeding groups are contained between the limiting lines λ 2502 and λ 2577, λ 2642 and λ 2671, λ 2849 and λ 2871, λ 2895 and λ 2978, λ 3043 and λ 3091. The sources which bring out these groups most

distinctly are the absorption furnace and the low-temperature emission spectrum, the former giving lines of shorter wave-length. In the high-temperature furnace, lines of higher classes are often comparable in strength with the pronounced low-temperature lines.

In the chromium spectrum, similar groups occur between λ 2365 and λ 2408, λ 2491 and λ 2592, λ 2726 and λ 2781, λ 2872 and λ 2911, λ 2968 and λ 3054. A long stretch of spectrum then contains only scattered low-temperature lines and the powerful triplet λλ 3579, 3594, 3605, until the group of Class I lines between λ 3883 and λ 3941 is reached. In this region, λ 3351.96 and λ 3379.18 are notable on account of their decided I A type, there being no other lines of comparable strength at low temperature in the neighborhood.

High-temperature lines.—The most interesting of these are the diffuse lines. They are numerous in both spectra, and occur in groups as distinct as those of any other type. In the vanadium spectrum, lines diffuse in the arc can usually be obtained sharp in the furnace and thus give improved wave-length values. This is true also for lines which in the arc are merely hazy patches. The diffuse lines of chromium are for the most part difficult to obtain in the furnace, and many of the new measurements of these lines were made in arc spectra exposed to make lines of this kind as sharp as possible. Some of the chromium lines are of an unusual type. They are moderately diffuse in the arc and retain about the same degree of diffuseness in the furnace, persisting thus sometimes at the medium-temperature stage. Three groups are noted in Table IV, near λ 2940, λ 3180, and λ 3410. In view of the exceptional behavior of these lines, it seems probable that they are of complex structure, and retain their satellites at the furnace temperatures.

Enhanced lines.—Both vanadium and chromium are very rich in ultra-violet enhanced lines, and the degrees of excitation required to produce them are similar to those required for the enhanced lines of titanium and iron, respectively. Vanadium enhanced lines frequently show self-reversal in the condensed spark; the stronger ones are prominent in the arc and persist as sharp lines in the furnace, in some cases at medium temperature. A comparison of the arc and high-temperature furnace serves to separate the enhanced lines by their relative weakness in the furnace, though

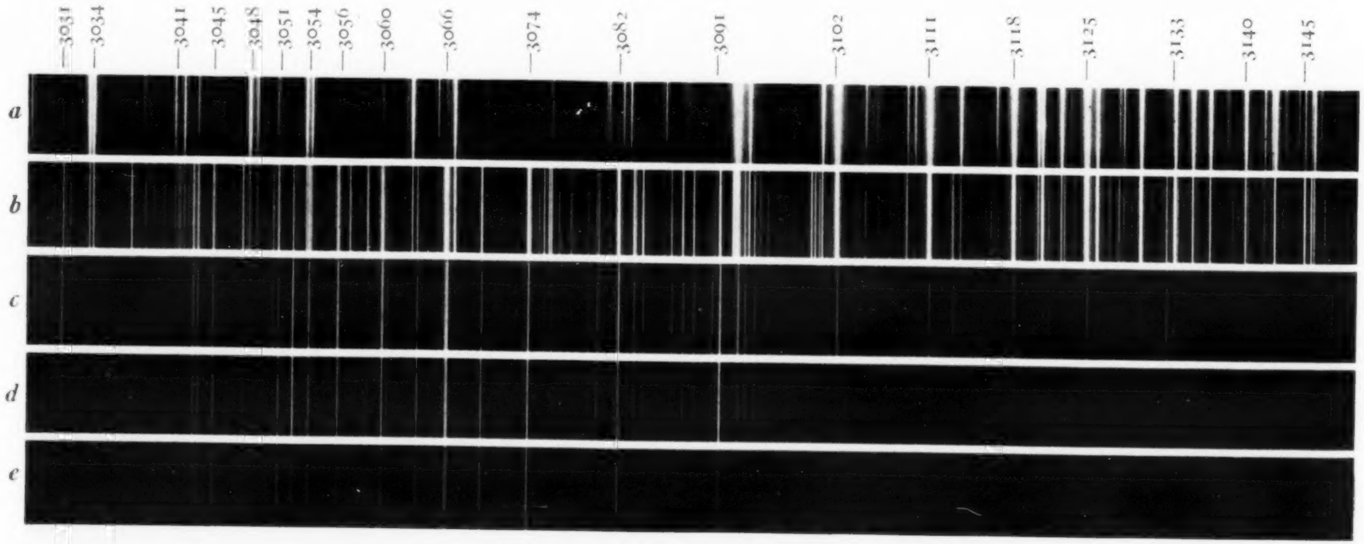
the lines designated as enhanced in the tables were selected by a direct comparison of arc and spark spectra photographed during this investigation. A group of enhanced lines near λ 2710, probably forming a multiplet, has its lines reversed unsymmetrically. A very strong group of reversible lines lies near λ 3100, its first member, λ 3093.14, being the strongest spark line in this region. Another set of reversible enhanced lines is near λ 2900, while near λ 3040 occur some very strong spark lines which do not reverse, are faint in the arc, and absent in the furnace. Such lines as these latter may be regarded as the "high-temperature" lines of the ionized spectrum.

The enhanced lines of chromium require stronger excitation than those of vanadium, and only some of the strongest of chromium near λ 2850, which reverse in the spark, show faintly in the high-temperature furnace. As a result, the enhanced lines of chromium, many of which have considerable strength in the arc, go as a whole into Class V. The available data indicate that 2200° for vanadium and 2600° for chromium are approximately the initial temperatures for the appearance of enhanced lines.

Description of the plate.—Plate V reproduces a section of the vanadium spectrum for the spark, arc, and three furnace temperatures. It shows a group of prominent low-temperature lines, together with enhanced lines which persist to varying degrees in the arc and furnace spectra.

Mount Wilson Observatory
August 1924

PLATE V



SPARK, ARC, AND FURNACE SPECTRA OF VANADIUM

a, Spark spectrum *b*, Arc spectrum
c, *d*, *e*, Furnace spectra at 2600°, 2300°, 2000° C., respectively

DOUBLE EXCITATION SPECTRA OF MAGNESIUM AND RELATED ELEMENTS

By J. B. GREEN and MAX PETERSEN

ABSTRACT

The group of five strong lines at about 2780 A in the spectrum of *Mg* are known to be Zeeman triplets of 3/2 normal separation, and constitute a group $1p_i-mp'_j$. Since their occurrence in the spectrum is found to have no correlation to the strength of the spark spectrum, it is argued that the origin of the p'-terms cannot be related to the ionized state of the atom. The wave-lengths of the group have been measured in arc, in vacuum, and in air, and show a shift to red in air. A line, probably $1p_1-4s$, was separated from the pp'-group and measured. The line 4380 A was measured and given the assignment $1P-mp'_1$. The lines 2768 A and 2765 A are found to be accompanied by a third, making a complete $1p$-triplet, whose variable term is in question.

The p'- and d'-terms of *Mg* and the other alkali earths are proposed as designating doubly excited states of the neutral atoms independent of metastable ionized states. Corresponding to these triplet terms, Saunders' singlet terms—mX, mY, mZ—are suggested as doubly excited singlet states. The evidence relating to these proposals, as found in the conditions of excitation of the primed terms, is presented.

This work on the spectrum of magnesium, begun before Paschen and Götze's *Seriengesetze der Linienspektren* came to hand, was undertaken to determine the proper assignment of the group of five strong lines at about 2780 A. They were suspected of being an example of a group such as Götze[1] first recognized in the spectra of other alkali earths, and gave the designation $(1P_i-mp'_j)$.[2] Bohr has suggested that the origin of these new p'-terms[3] lay in the peculiar metastability of the lowest δ-term of the ionized spectra of these atoms. On these premises such a group should not be found in the spectrum of magnesium, for its 1δ-term has not this metastability. For the cases of calcium, strontium, and barium,

[1] *Annalen der Physik*, **66**, 285, 1921.

[2] The authors have used Fowler's nomenclature in this paper.

[3] The characteristics of these p'-terms are that in combination with p-terms they give rise to lines whose Zeeman patterns are those predicted from Landé's theory for combinations of p-type terms with other p-type terms. Further, the frequency differences of these p'-terms are closely in the ratio 2:1, a p-type characteristic, and also the inner-quantum numbers, determined from known combinations, are 2, 1, 0—another p-type characteristic. However, the new terms do not fit into the Rydberg series of known p-terms.

Bohr's[1] suggestion has been discussed in detail by Wentzel.[2] The conditions giving rise to lines involving p'-terms in the spectrum of magnesium have led the authors to believe that these terms are due rather to multiple excitation of the neutral atom than to any property of the ionized atom. The evidence relating to the appearance of these p'-terms in magnesium is the chief subject of this report.

Apparatus.—The sources used were an arc *in vacuo* (i.e., in several mm hydrogen), an arc and spark in air. The vacuum arc, with which most of the plates were taken, was between electrodes of metallic magnesium, the negative electrode being viewed end-on. A detailed description of this arc will be included in a forthcoming report on other matters. Spectrograms were taken with the 21-foot concave grating in the Rowland mounting of the laboratory, with a quartz instrument of moderate dispersion, and with a Hilger wave-length spectrograph of glass. The plates were measured on a Société Genevoise engine.

Experimental.—Three of the five lines of the 2780 A group fall at wave-lengths very near those calculated for the sharp triplet $1p_i-4s$. The strength of the five lines is much too great to permit of the assignment of any of them to the triplet, and no published separation of the triplet from the other group was known. The first plates of the vacuum-arc spectrum, taken in the third and fourth orders of the concave grating, showed that no other lines than the five were easily observable. Their Zeeman pattern was therefore first determined, using a spark in air. The magnetic field, 12 mm in diameter and 3.4 mm long, was measured by means of a bismuth spiral, using the results of Blake[3] for the magnetic variation of resistance. Four plates gave the results shown in Table I. The polarization of the components of each line was found to be that of a normal triplet. The measured separation of the triplet is closely 3/2 the "normal" separation, which would be 0.145 A, a value which justifies the assignment of the lines to a pp'-combination, according to Landé.[4] Paschen and Götze[5] give the group this assignment.

[1] *Drei Aufsätze über Linienspektren, etc.* (original ed.).

[2] *Physikalische Zeitschrift*, **24**, 104, 1923; **25**, 182, 1924.

[3] *Annalen der Physik*, **28**, 449, 1909.

[4] *Zeitschrift für Physik*, **5**, 231, 1921.

[5] *Seriengesetze*, p. 101.

Third-order plates of the group in the vacuum arc and in the arc in air were measured for wave-length against tertiary iron standards (second order), only such being used as showed agreement to a single millangstrom between the several published measures.

TABLE I

($H = 26{,}630 \pm 100$ Gausses)

Line	−Comp.	+Comp.	Average
	mm	mm	mm
2776.7A..........	1596	.1717	.1652
2778.3............	.1633	.1650	.1642
2779.8............	.1656	.1641	.1648
2781.4............	.1742	.1597	.1669
2783.0............	.1701	.1672	.1686
Average.......	....	....	.1659
Third-order scale, 0.887 A/mm................			$\Delta\lambda = .147$ A

The measured wave-lengths, together with the other similar values available, are summarized in Table II. The line 2778 was difficult to measure in the arc in air on account of the broadening of the nearby second-order image of the line 4167.276 I.S. (authors' vacuum-arc value). The air-vacuum displacements have an aspect

TABLE II

($\lambda\lambda$ in I.S.)

Line	Authors' Vacuum Arc	Air Arc	Air−Vacuum	Nacken* (Air)	Rowland Arc−.100
2776..................	.691(6)	.696	.005	.704	.698
2778..................	.272(4)	.275	.003	.289	.281
2779..................	.834(10)	.839	.005	.853	.835
2781..................	.418(4)	.422	.004	.431	.421
2782..................	.973(6)	.978	.005	.989	.977

* *Zeit. Wiss. Phot.*, **12**, 59, 1913.

of possibly being intensity error, but that suspicion is not supported by the measures of different plates on which the images were of different strength on account of variation of exposure.[1] The line 2779.8 A, which is a coincidence of two combinations, $1p_1 - mp'_1$

[1] Details of the determination of these wave-lengths will appear in a report on other similar measures.

and $1p_2 - mp'_2$, was always more likely to reverse than were the other lines of the group. In the arc in air it was markedly strengthened as compared with the other lines. Only in two fifth-order vacuum plates did it show any evidence of being resolvable into two lines. In all the measures of the wave-lengths in Table II, the line 2779.8 A was treated as a single image. The diagram below represents the authors' conclusions regarding the location of the group.

		(4) 2781.418 *35942.30* *20.47*			mp'_3
(6) 2782.973 *35922.03* *40.74*	*40.74*	(10) 2779.834 *35962.77* *40.71*	*19.97*	(4) 2778.272 *35982.74*	mp'_2
(10) 2779.834 *35962.77*	*40.71*	(6) 2776.691 *36003.48*			mp'_1
$1p_1$		$1p_2$		$1p_3$	

The sharp triplet $1p_i - 4s$, whose place in the series brings it closely into coincidence with three of these pp'-lines, was sought for on a number of longer exposures of third-order plates. On several of these a line was found close to λ 2781.418 and much fainter than it. The line was very sharp and easily separated from the stronger neighbor. It was photographed nearly a dozen times without doubt, and was found to be quite as strong on some plates from which the "band spectrum" was nearly missing as on others where this spectrum was quite well developed. It may therefore be definitely said that it does not belong to that many-lined spectrum. A cursory examination of the plates of the 2780 region demands this care before the line can be named $1p_1 - 4s$. Measures on four of these plates gave its wave-length

2781.292 I.S., *35943.93* cm^{-1}.

Fowler has calculated for $1p_1-4s$, *35943.6* cm^{-1}. The measured line is believed to be the first of the triplet. The next could not have been found on the authors' plates on account of the second-order image of λ 4167.276.

A new combination with these p'-terms was found in the line $1P-mp_1'$. The line was measured on one grating plate, giving the wave-length

$$1P-mp_1', \ 4380.376 \text{ I.S.}, \ 22822.71 \ \mathrm{cm}^{-1}.$$

It was found on several plates with smaller instruments. The region of the line $1P-mp_2'$ was densely occupied with lines of apparently molecular origin.

Having determined accurately the locations of these lines, $1p_i-mp_j'$ and $1P-mp_i'$, attention was directed to the question of the conditions for the excitation of the lines and the appearance of the p'-terms in the magnesium spectrum. For this purpose there were available a large number of photographs—over a hundred—taken with every possible variation of conditions of the vacuum arc and arc in air, as well as some published observations by other authors. The vacuum-arc negative electrode was a rod of metallic magnesium, surrounded, for the present purpose, by a tube of furnace magnesia. The operation of the arc spent the metal until the pit formed by the tube became as deep as possibly 2 cm. This deep pit was usually viewed end-on; but it could also be seen from the side across its mouth from which a very bright green flare extended for several millimeters, varying with the hydrogen pressure. Variation of current varied chiefly the rate of disappearance of magnesium from the cathode, and, the vacuum being held the same, the density and temperature of the *Mg*-vapor in the magnesia tube. The spectrum photographed across the mouth of the pit was more arc- than spark-like. With currents high enough to vaporize the metal at a rate of perhaps 1 cm of rod per ten minutes as compared with the usual rate of a like mass per three hours, the arc at the mouth of the pit was little different from the arc in air save that the lines were much sharper under high resolution. In the spectrum

[1] Similar combinations noted by one of the authors in the spectra of *Ca*, *Sr*, and *Ba* were reported by Saunders and Russell (*Physical Review*, **22**, 201, 1923).

thus photographed, the pp'-lines were much stronger in relation to the principal doublet at 2795 and 2802 than they were in the spectrum taken from the whole depth of the pit. Other photographs taken so as to put the image of only the positive spot of the arc on the slit showed the group to be not greatly weakened in that part of the source from which the spark spectrum is conspicuously absent. Only in this positive region of the arc in vacuum was the line $1P-mp_1'$ found to be at all intense. (This line occurs also in the arc in air, recorded by Exner and Haschek[1] with intensity 1, and again at the anode of a discharge in 3 cm of oxygen observed by Brooks.)[2] The persistence of the pp'-group and the line $1P-mp_1'$ in a portion of the vacuum arc in which the spark spectrum is suppressed seems to the authors to be definite evidence that the p'-terms are not to be associated with the ionized atom in their origin.

The presence of these primed terms in the triplet spectra of the alkali earths has given rise to the question whether terms of a similar origin may not occur in the singlet spectra as well. In the spectra of *Ca* and *Sr*, Saunders[3] has reported terms mX, mY, and mZ, which combine with a few of the series terms both of the singlet and triplet spectra. It seems to the authors very probable that these terms are the singlet analogues of the primed terms of the triplet spectra. With this in mind, it becomes natural to expect to find the same sort of combinations in the spectrum of *Mg*. A group conspicuous in the arc in air and sometimes in the vacuum arc is the pair λ 2768 and λ 2765. These two, of which the longer is very much the stronger, have the separation $1p_2-1p_1$. They are assigned in Fowler[4] as $1p_1-5D$, $1p_2-5D$. This assignment, which is numerically justified, is otherwise rather unsatisfactory. In the first place, no evidence of the earlier members of that series, combining with $4D$, $3D$, and $2D$, could be found on plates on which the pair λ 2768 and λ 2765 were very strong. Further evidence that these two lines are not related to a D-term is given by the discovery of a third line, completing with the known two a normal-arc triplet.

[1] *Die Spektren der Elemente bei normalem Druck* (1911).

[2] *Astrophysical Journal*, **29**, 184, 1909.

[3] *Astrophysical Journal*, **56**, 73, 1922.

[4] *Report on Series in Line Spectra*, 1922.

This third line, λ 2763.68 A, should not occur if the initial term were $5D$, because the change of inner-quantum number would be greater than unity. (As in the case of the line $1p_1-4s$, there is danger of a band line being selected for the series assignment in mind. The same procedure as before was necessary to convince the authors that this very faint third line was not in reality a member of a band. It has, in fact, two near neighbors that are apparently members of a band thereabouts, and which were measured on several plates showing them not to have the proper wave-length to complete a triplet with the two known lines.) The wave-length given for this third line is the mean of measures of three plates with the quartz instrument, dispersion about 12 A/mm. The wave-lengths of the two stronger lines, measured on one third-order grating plate, were

$$\left.\begin{array}{l} 2768.352 \text{ I.S., } \mathit{36111.92} \text{ cm}^{-1} \\ 2765.237 \text{ I.S., } \mathit{36152.61} \text{ cm}^{-1} \end{array}\right\} \mathit{40.69}$$

The difference between these wave-numbers and Fowler's values of the $1p$-terms leaves a variable term of 3648.6 cm^{-1}, only 0.1 different from his value of $5D$ obtained from 4351.91 A. The authors measured this line, $1P-5D$, on four second-order and two third-order plates, giving the wave-length

$$1P-5D,\ 4351.912 \text{ I.S., } \mathit{22971.97} \text{ cm}^{-1}.$$

This measurement gives the value of the $5D$-terms coincident exactly with the variable term of the 2768 triplet, assuming only that the $1P$-term is not in error. If, then, the triplet is not to be assigned to $5D$, it leaves an apparently difficult problem in the discovery of any other lines involving the new term. The authors' conjecture that this triplet belongs to a term analogous to Saunders' mX-term in the other elements mentioned would suggest that in similarity to those spectra the term mX should combine with $1P$. That possibility would be verified by a very close satellite to the line λ 4351 ($1P-5D$). The authors' term-values indicate a difference of only about 0.02 A, a separation that would not be attained in view of the disparity between the intensities of the lines. On no plates was it possible to ascertain any complexity of the line λ 4351. It seems

never to reverse in the arc in vacuum, nor do the other diffuse singlet lines. There may be noted also the possibility that the term in question is a d'-term. That would also result in a complete triplet, since the separation of the $2d$-triplet is apparently beyond the power of the authors' grating. Having in mind the possibility that the triplet at 2768 A may be due to a new term similar to other primed terms, the authors examined the appearance of the two stronger lines of the triplet on many quartz spectrograph plates. On a number of these the location of the source of particular lines in a restricted part of the vacuum arc is evident from the length and strength of the image on the spectrogram. All such plates show these two lines to have no enhancement in parts of the source strong in spark spectrum. These indications mean only that any term proposed instead of $5D$ as the variable term of this triplet can have no spark affiliation.

The suggestion that the primed terms of certain alkaline earth spectra are related to a metastable 1δ-term of the ionized atom permits of two somewhat different physical interpretations. One, given by Wentzel[1] in his first paper,[2] involves the neutralization of a 1δ-ionized atom; the other involves the multiple excitation without ionization of an atom previously singly excited, implying that the metastability of the ionized 1δ (3_3 for *Ca*) orbit is a physical characteristic shared by the corresponding orbits of the excited neutral atom. Wentzel's suggestion demanding initially the presence of 1δ-ionized atoms should lead to a correlation between the excitation of primed terms and the spark spectrum. Either suggestion should lead to a difference of behavior between *Ca*, whose 1δ-term is "metastable" and *Mg*, whose like term is not.

[1] *Loc. cit.*

[2] Wentzel discusses *Ca*, *Sr*, and *Ba* somewhat as follows: According to Bohr both valence electrons of *Ca* are normally in 4_1 orbits. The removal of one of these to outer orbits and its subsequent return gives rise to the ordinary arc spectrum. Now, Bohr says, the 3_3 (1δ) condition of the ionized atom of *Ca*, for instance, is a very highly probable state because of the low value of its potential energy. It is, however, not so stable as the 4_1 (1σ) condition, which has an even lower potential energy. The ionized atom will try to get from the 1δ- into the 1σ-state. But it cannot do this under ordinary conditions since the change of azimuthal quantum number is greater than unity. If, however, the ionized atom in the 1δ-state picks up another electron by collision, the selection principle will no longer restrict azimuthal quantum numbers

The most conspicuous lines involving primed terms are the first pp'-group (4300) of *Ca*, and the one known pp'-group of *Mg* (2780). In the spectrum of *Ca*, A. S. King[1] has found that the first pp'-group appears very strong in furnace spectra, which show no spark spectrum save the first principal doublet (H, K). The pp'-lines appear at the lowest temperatures observed and are not enhanced at higher temperatures. In other sources, King found these lines weakened with increased strength of spark lines. Certainly there is no dependence upon ionization for the establishment of p'-terms of *Ca*. The observations of King[2] for the *Ca* pp'-group ($\lambda\lambda$ *ca* 4300) are closely paralleled by the other primed terms of *Ca* and the like terms of *Sr* and *Ba*. In the spectrum of *Mg* the authors' observations have shown that there is no correlation between the pp'-lines and the spark spectrum. Similar evidence is found in Foote, Meggers, and Mohler's[3] electron impact spectra of *Mg*.

There is no experimental evidence found which will distinguish between the manner of excitation of the primed terms of *Ca*, *Sr*, and *Ba*, and of *Mg*, which last-named atom differs from them in not having "metastable" 1δ-ionized orbits. It is thus seen that in the manner of their excitation there is no physical cause for relating these primed terms of certain of the alkaline earths to the "metastable" 1δ-ionized orbits.

Considering the primed terms to designate doubly excited neutral states, it is of interest to see what evidence there may be of

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and the electron goes into a 4_1- from a 3_3-orbit. If, while this is happening, the newly captured electron is in a 4_2-orbit, the result will be the emission of one line of a pp'-group; and if the new electron is in a 3_3-orbit, the emission of one line of a dd'-group. The term difference $1\sigma - 1\delta$ of the ionized atom should be of the order of magnitude of the wave-number of the lines emitted. It is possible by this explanation to account for such pp'- and dd'-groups in *Ca*, *Sr*, and *Ba*, but not in the spectra of *Mg* and Al^+, since the 1δ-state of Mg^+ and Al^{++} has not the peculiar metastability of the corresponding state of the atoms of Ca^+, Sr^+, and Ba^+. Wentzel suggested that other similarly metastable states of the ionized atoms would have to be held responsible for the other recognized pp'- and dd'-groups than those he discussed. Evidence of such states other than the 1δ is, however, not at hand. (More recently he has doubted that the ionized atom is involved in these cases, where the 1δ metastability is missing.)

[1] *Contributions from the Mount Wilson Observatory*, Nos. 32, 35, 38, 150. *Astrophysical Journal*, **28**, 389, 1908; **29**, 63, 381, 1909; **48**, 13, 1918.

[2] *Loc. cit.*

[3] *Philosophical Magazine*, **42**, 1002, 1921.

the probability of such states arising from *successive impacts*, rather than from neutralization of an ionized atom. This probability is proportional to the life of the *initially excited* state. The evidence for especial permanence is most conspicuous in the case of the lowest p-triplet of the elements of the second column. The normal state of all these atoms is the $1S$, the resonance line $1S-1p_2$. If atoms are left by impact in the $1p_i$-states, there should result an accumulation in these states, for the only one from which return is possible in accord with the inner-quantum restrictions is the $1p_2$. Of such accumulation of p-atoms at least two sorts of evidence are at hand. One of these is the easy reversal of the two subordinate series, while other and more direct evidence is found in the studies of the impacts of electrons with second-column atoms and of their consequent spectra. In the *Mg* impact spectra of Foote, Meggers, and Mohler,[1] the strength of several lines other than the resonance line at low voltages and small currents leads these authors to attribute a particularly long life to the $1p$-states. The explanation of the *Mg* p'-terms as due to multiple excitation is particularly supported by their appearance in these spectra. The pp'-group appears with almost the earliest arc lines, at 10 volts (*ca*, 300 m.amp. current). From 10 to 60 volts the group was found to have no great rise of intensity using similar currents, but the lines of the spark spectrum had intensities increasing with the voltage. The lines $1P-mp'_1$ and λ 2768 and λ 2765 Å were observed to have almost identical behavior with the pp'-group.

For two other elements of the second column similar permanence of the lower orbits is found. Cario and Franck[2] in their work on sensitized fluorescence of *Cd*-vapor give evidence of a long life of the $1p$-states for *Cd* and of the *Hg* $1p_2$-state. The work of Webb[3] and that of Franck and Einsporn[4] on *Hg*-vapor give similar evidence for all its $1p$-states. The availability of excited atoms, possibly in $1p_i$-states, should result in multiple excitations in sources in which frequent impacts of atoms with one another or with electrons are

[1] *Loc. cit.*

[2] *Zeitschrift für Physik*, **17**, 202, 1923.

[3] *Physical Review*, **23**, 294, 1924.

[4] *Zeitschrift für Physik*, 2, 18, 1920.

probable. Such sources, as furnace and arc in air, are found to be highly favorable means for exciting lines of primed terms. The low-temperature characteristics of these lines are vital points to consider in discussing the origin of their terms.

Epstein[1] has concluded, from the application of the "Correspondence Principle" to the study of a simple divalent atom with coupled electrons, that with the breakdown of the azimuthal quantum restrictions may be associated the possibility of the appearance of lines involving the simultaneous return of both electrons. It should be pointed out that only in special cases do the lines involving primed terms imply the simultaneous return of both electrons.

An important feature of the p'-terms is their habit of combining only with the terms $1p_i$ and $1P_j$, in which respect *Mg* is again indistinguishable from the other elements in its column. It is evidently possible that the p'-states consist of a second excitation of an atom having one electron initially in a p-orbit (3_2 for *Mg*). These orbits are the next above those of the normal ($1S$) atom. If, then, the second excited electron return from its outer orbit to the lowest s-orbit (for *Mg* 3_1), the jump will give one or the other of the two strong combinations known. If the outer orbit of the initial state be a p-orbit (modified, of course, by the new position of the other electron but retaining its $k=2$), then the combinations $(1p-mp')$ and $(1P-mp')$ imply no departure from the ordinary azimuthal quantum restrictions, or from the inner-quantum restrictions, nor demand the simultaneous return of both the electrons. Of the other primed terms listed by Saunders and Russell,[2] such simple behavior is not reported. They obviously do involve jumps of both electrons in some cases.

The facts assembled above show that the primed terms of the alkaline earths occur under similar physical conditions without regard for the presence of a "metastable" 1δ-term in the spark spectrum. They show that the primed terms are likely to be found with dense currents and many low-speed impacts, and are not enhanced by high-speed impacts and the attendant ionization. Primed

[1] *American Physical Society Abstracts* (128th meeting), *Physical Review*, **24**, 205, 1924.

[2] *Loc. cit.*

terms may therefore be said to designate doubly excited neutral states not dependent on ionization for their establishment.

The conflict between these physical characteristics of the primed terms and the numerical support that Wentzel[1] adduces in his second paper for 3_3 orbits in *Ca* may be real or not. He deduces from the values of three p'-triplets that the convergence energy of the p'-terms lies as far above that of the common zero (∞s, ∞p, ∞d) as the 1δ-term lies above the 1σ of the ionized atom. This confirms him in his opinion that these three p'-states have in common one electron in a 3_3-orbit. By his series he predicts a fourth p'-term as yet unobserved. Against this numerical argument there exists a preponderance of evidence that the $1p_i$-orbits are "metastable" enough to give opportunity for multiple excitation, and very little that the 3_3-orbits are similarly long lived.

MADISON, WISCONSIN
August 15, 1924

[1] *Loc. cit.*

ORBIT OF THE SPECTROSCOPIC BINARY 66 ERIDANI

By EDWIN B. FROST and OTTO STRUVE

ABSTRACT

The *orbit* of this spectroscopic binary is based upon measurements of eighty-three spectrograms. The velocities are determined for each component, which have a maximum relative velocity of 220 km/sec. Each component is of *spectral type B9*. The *period* is $5^{d}.52242$. The preliminary elements were slightly improved by a least-squares solution.

The K lines of calcium are sharp in each component and yield the same radial velocities as do the other lines. It is evident that there can be no stationary K component, as this should be easily visible at maximum separation of the oscillating K lines.

The position of this star for 1900 is $\alpha = 5^{h}1^{m}.8$, $\delta = -4°47'$. Its visual magnitude is given as 5.19 and its photographic magnitude as 5.17, by the Harvard observers. It is Number 1213 in Boss's *Preliminary Catalogue*, where the components of its proper motion are given as $+0^{s}.0006$, $+0''.008$. No determination of the parallax of this star by trigonometric or spectroscopic methods has yet been published.

The spectral type of the star was called A0 in *H.R.*, but in the new *Henry Draper Catalogue* this is revised to B9. The hydrogen lines, β, γ, and δ, are broad and diffuse. We must depend for the radial velocity chiefly upon the magnesium line λ 4481. The other lines which were used for determining the velocity, in order of their distinctness, were $\lambda\lambda$4549 (*Ti-Fe*), 4395 (*Ti*), 4045 (*Fe*), and 4077 (*Sr*). The spectra of both components are visible, the lines of the fainter component being only slightly weaker than of the stronger. When the separation of the lines is large, the hydrogen lines can also be used in determining the velocity. On the first plate, taken October 1, 1915, the lines appear single, but on the second plate, December 13, 1915, the lines were at once seen to be double, with a separation of over 200 km per second. The binary character of the star was not announced until after the period, $5^{d}.52$, had been found and about sixty spectrograms had been secured.[1] Its binary character was

[1] Edwin B. Frost, *Astrophysical Journal*, **48**, 260, 1918.

TABLE I

Plate	G.M.T.	Observed By	Measured By	Qual.	Vel. I	Vel. II
					km/sec.	km/sec.
IB 4257...	1915, Oct. 1.942	B, S	F	v.g.	+ 42.0	....
4318...	Dec. 13.777	C, S	F	f.	154.0	−88.7
4326...	Dec. 14.732	F, S	F	g.	94.0	33.5
4330...	Dec. 27.654	B, S	C	g.	140.0	44.5
4338...	Dec. 28.747	S	σ	g.	79.7	16.9
4345...	1916, Jan. 3.640	B, H, S	C	g.	48.0	....
4358...	Jan. 17.565	H, S	σ	g.	40.8	....
4361...	Jan. 17.728	H, S	σ	f.	28.4	....
4367...	Jan. 18.571	C, S	C	g.	132.2	42.2
4369...	Jan. 18.654	C, S	C	g.	135.1	51.4
4376...	Jan. 22.573	C, S	C	f.	52.3	15.2
4378...	Jan. 22.665	C, S	C	f.	32.5	....
4385...	Jan. 23.681	S, H	C	f.	118.3	36.2
4393...	Jan. 31.612	S, H	Lz	f.	84.9	33.7
4394...	Jan. 31.711	S, H	Lz	p.	98.9	22.1
4400...	Feb. 7.559	B	σ	f.	127.8	62.1
4406...	Feb. 15.632	S, H	Lz	f.	126.3	63.9
4414...	Feb. 18.567	S, H	σ	v.p.	113.9	77.8
4417...	Feb. 29.556	S, H	σ	f.	121.3	59.7
4420...	Mar. 3.539	B, Lz	Lz	v.g.	105.1	49.9
4421...	Mar. 3.591	B, S	Lz	g.	111.3	51.7
4422...	Mar. 3.644	B, S	Mk	f.	105.7	52.3
4432...	Mar. 10.504	B	Lz	f.	106.9	35.4
4433...	Mar. 10.567	B, S	Lz	f.	114.1	37.6
4434...	Mar. 10.619	B, S	Lz	g.	113.6	50.1
4440...	Mar. 13.574	B, H	Lz	f.	139.6	63.4
4441...	Mar. 17.554	S, H	Lz	f.	102.1	30.9
4442...	Mar. 17.596	S, H	σ	p.	53.0	....
4444...	Mar. 20.553	B, S	σ	f.	76.7	14.4
4450...	Apr. 4.579	B, S	Mk	f.	112.5	29.0
4454...	Apr. 14.564	B, H, S	Mk	v.p.	33.3	....
4628...	Sept. 8.942	C, S	Mk	f.	113.1	60.2
4636...	Sept. 15.938	B, S	σ	p.	36.0	....
4638...	Sept. 20.942	B, S	σ	g.	141.7	48.8
4644...	Sept. 23.916	B, S	Mk	f.	116.7	55.8
4650...	Oct. 4.826	B, Mk, S	Mk	f.	114.8	46.4
4652...	Oct. 4.948	B, Mk, S	Mk	g.	104.4	54.6
4657...	Oct. 7.818	B, Mk, S	Mk	f.	96.2	50.5
4664...	Oct. 13.833	Mk, S	Mk	g.	36.6	....
4666...	Oct. 13.955	Mk, S	Mk	g.	30.6	....
4675...	Oct. 27.720	Mk	Mk	f.	25.5	....
4676...	Oct. 27.935	B, S	Mk	p.	41.6	....
4681...	Nov. 4.763	B, S	Mk	g.	42.7	....
4683...	Nov. 4.985	Mk, S	Mk	p.	39.6	....
4690...	Nov. 10.699	B, S	Mk	v.g.	33.2	....
4692...	Nov. 10.803	B, S	σ	f.	23.4	....
4701...	Nov. 29.868	Mk, S	Mk	v.p.	37.0	....
4730...	1917, Jan. 1.541	B, F, S	Mk	v.g	83.5	43.6
4748...	Jan. 5.730	B, S	Mk	v.g.	112.6	51.4
4752...	Jan. 8.642	Mk, S	σ	g.	116.0	88.8
4769...	Jan. 19.650	B, S	Mk	v.g.	120.0	77.2
4771...	Jan. 19.754	B	σ	p.	106.2	56.0
4843...	Mar. 23.568	Mk, S	Mk	p.	+ 85.0	−10.0

TABLE I—*Continued*

Plate	G.M.T.	Observed By	Measured By	Qual.	Vel. I	Vel. II
					km/sec.	km/sec.
5130...	1917, Dec. 21.639	Wk, S	σ	g.	+ 31.0	....
5152...	1918, Jan. 7.606	Wk, S	σ	g.	39.2	....
5166...	Jan. 18.628	Wk, S	Bk	f.	15.6	....
5205...	Mar. 1.540	B, Wk, S	Bk	f.	114.6	−67.0
5212...	Mar. 15.549	B, Wk	Bk	g.	137.7	81.7
5223...	Mar. 22.560	B, Wk	σ	f.	30.4	....
5453...	1919, Feb. 7.661	B, S	σ	g.	142.3	63.0
5457...	Feb. 10.531	Wk	Bk	g.	116.7	48.9
5665...	1920, Jan. 9.687	Pr, S	Bk	f.	130.0	30.2
5679...	Feb. 9.639	Bk, S	σ	f.	123.4	76.5
5688...	Feb. 23.578	Bk, Pr, S	σ	v.p.	109.3	61.5
5696...	Mar. 5.619	B, S	σ	p.	146.6	66.0
5705...	Mar. 8.564	Bk, Pr, S	σ	f.	112.6	83.6
6064...	Nov. 12.743	B, S	Bk	f.	25.2	....
6071...	Nov. 15.739	Bk, S	Bk	f.	40.6	....
6075...	Nov. 19.829	B, Bk, S	Bk	f.	123.4	40.8
6081...	Dec. 6.701	Bk, S	σ	f.	129.5	54.6
6090...	Dec. 27.659	Bk, S	Bk	f.	5.7	....
6112...	1921, Jan. 28.550	Bk, S	Bk	f.	116.2	36.9
6119...	Jan. 31.565	Bk, S	Bk	p.	104.7	46.1
6120...	Feb. 4.591	Bk, S	σ	p.	91.6	38.9
6128...	Feb. 14.560	Bk, S	Bk	v.p.	43.3	56.8
6136...	Feb. 18.583	Bk, S	σ	g.	117.3	83.3
6280...	Oct. 31.851	B, σ, S	σ	f.	100.5	26.3
6292...	Nov. 11.808	B, σ, S	σ	p.	97.3	35.3
6341...	1922, Jan. 9.592	σ, S	σ	v.g.	28.3	....
6351...	Jan. 13.586	σ, S	σ	g.	119.9	51.7
6359...	Jan. 16.717	σ, S	σ	v.p.	120.0	62.4
6374...	Jan. 27.608	σ, S	σ	f.	118.9	78.3
6380...	Jan. 30.602	σ, S	σ	f.	+125.1	−50.3

In Table I the names of the observers and measurers are indicated as follows: B=S. B. Barrett; Bk=Miss D. W. Block; C=C. C. Crump; F=E. B. Frost; H=E. P. Hubble; Lz=J. Lemkovitz; Mk=G. S. Monk; Pr=J. Paraskévopoulos; σ=O. Struve; S=F. R. Sullivan; Wk=Miss E. W. Wickham.

f.=fair; g.=good; p.=poor; v.=very.

independently announced almost simultaneously by the Lick Observatory.[1]

The observational material on which the present orbit has been based, consisting of eighty-three plates, is found in Table I.

Nine normal places were formed for each component, as given in Table II.

A preliminary graphical solution was made, with a period of $5^{d}52242$ (see Table III). A least-squares solution was carried out

[1] W. W. Campbell, *Publications of the Astronomical Society of the Pacific*, **30**, 352, 1918.

according to the method proposed by the late W. F. King,[1] with the results indicated in Table III, but it will be seen that the solution by least squares has not materially improved the representation, $[pv^2]$ being reduced only from 297 to 223.

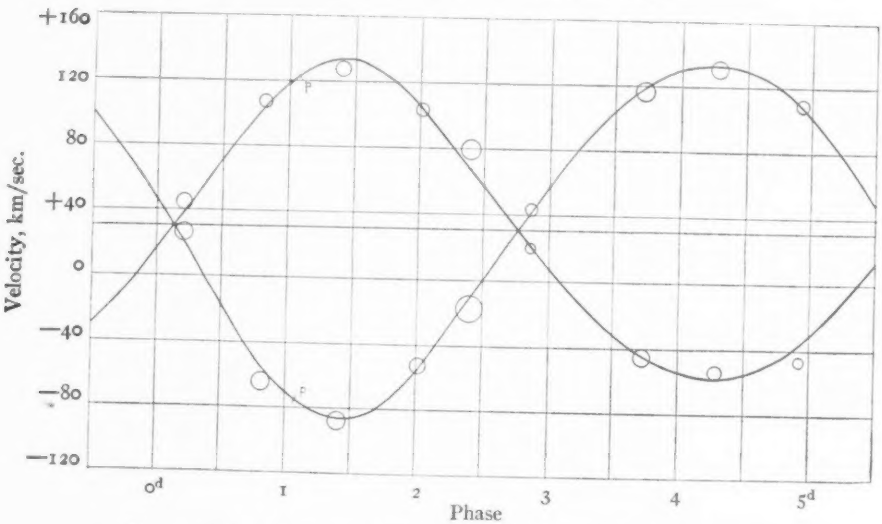

FIG. 1.—Velocity curve of the spectroscopic binary 66 Eridani. (Phase 0^d = J.D. 2,433,086,500.)

TABLE II

NORMAL POINTS

Phase in Days	Component I				Component II			
	Weight	Velocity	O.−C. Prelim.	O.−C. Final	Weight	Velocity	O.−C. Prelim.	O.−C. Final
		km/sec.				km/sec.		
0.206....	0.8	− 47.6	−9.2	− 9.5	0.6	+109.0	−5.0	−0.5
0.810....	.5	+ 45.0	+5.5	+ 5.3	.4	+ 26.4	+5.5	+5.8
1.395....	.6	107.6	+0.8	+ 1.3	.4	− 64.6	−6.0	−8.8
2.015....	.5	127.6	−7.8	− 5.2	.4	87.3	+5.0	−0.2
2.396....	.7	103.6	+4.8	− 1.8	.5	52.8	+7.6	+1.9
2.869....	0.3	79.1	6.9	+11.6	.2	− 18.0	−0.3	−6.7
3.720....	1.0	+ 19.8	2.4	0.1	.7	+ 43.2	+1.8	0.1
4.280....	0.4	− 45.9	0.5	0.9	.3	116.5	−5.9	2.9
4.924....	0.6	− 54.5	+6.5	+ 5.8	0.4	+131.1	−8.5	−3.8

The velocity curves of both components are shown in Figure 1. The circles represent the normal points collected in Table II. The

[1] *Publications of Dominion Observatory*, Ottawa, 1, 327, 1911.

radius of each circle equals the probable error of the corresponding normal point.

It is obvious that, in measurements of such a spectrum, at times when the lines are not wholly separated, the setting will not be upon either component, but rather upon the center of gravity of the two, which will result in a large probable error. The probable error of one normal place of weight unity is ± 3.0 km/sec., and the probable error from one spectrogram averages about ± 13.0 km/sec.

It will be seen that the sum of the mass functions for the two components is 4.7 times the mass of the sun. If the average value of $\sin^3 i$, 0.65, applies here, then the total mass would be 7 ⊙.

TABLE III

ELEMENTS

	Preliminary	Corrections	Final	Probable Errors
P	$5^d.52242$		$5^d.52242$	
γ	+31.0 km/sec.	−0.1	+30.9	±1.0 km/sec.
e	0.07	+0.004	0.074	0.013
K_1	98.0 km/sec.	−1.0	97.0 km/sec.	2.4 km/sec.
K_2	116.0 km/sec.	−5.0	111.0 km/sec.	2.4 km/sec.
ω	$335^\circ.0$	$+0^\circ.9$	$335^\circ.9$	$1^\circ.1$
T	J.D. 2,423,087.575	$+0^d.0003$	J.D. 2,423,087.5753	$\pm 0^d.0004$
$a_1 \sin i$			7,300,000 km	
$a_2 \sin i$			8,400,000 km	
$m_1 \sin^3 i$			2.5 ⊙	
$m_2 \sin^3 i$			2.2 ⊙	
m_2/m_1			0.87	

The K line is quite sharp in the spectrum of each component. K yields, within the uncertainty of measurement, the same radial velocity as do the other lines. The K lines are evidently due to the stars and cannot have their origin in any calcium cloud. The maximum separation of the two K lines, amounting to 3 A (0.2 mm on our plates), is wide enough so that any K absorption due to an intervening cloud should be visible. Careful examination shows that it is not present. This fact is of significance because in the region around 66 Eridani stars showing stationary K lines are especially abundant. Such lines are found in the spectroscopic binaries η, i, θ_1 and θ_2, ϕ_1, and δ Orionis, and also in several single stars, such as 65 ψ Eridani and others. The absence of stationary

calcium lines in 66 Eridani seems to support Dr. J. S. Plaskett's view, expressed in his important paper in the *Monthly Notices*,[1] that such lines do not occur usually in stars of spectral types later than B3.

We are indebted to Miss Mary Howe for assistance in the computations involved in this paper.

YERKES OBSERVATORY
August 5, 1924

[1] *Op. cit.*, **84**, 80, 1923.

Minor Contributions and Notes

FOURTEEN SPECTROSCOPIC BINARIES

By EDWIN B. FROST

ABSTRACT

Data are given for fourteen stars, the radial velocities of which have been found to be variable at the Yerkes Observatory. One star is of class B8, another of Go, and the remainder range from Ao to A5.

The stars listed below have been found here to be spectroscopic binaries, many of them during the last decade or more, but their publication has been deferred until more data could be given as to their variation or their orbits.

TABLE I

Name	Boss No.	α 1900	δ 1900	Vis. Mag.	Spec. Type	No. of Plate	Range of Velocity	Found By	Remarks
32 l Persei	757	$3^h 14^m 8$	$+42°58'$	5.0	A2	5	+18 −38	L	1
49 d Orionis	1392	5 34.0	− 7 16	4.9	A3	5	83 83	F	2
54 λ Geminorum	1886	7 12.3	+16 43	3.6	A2	4	60 −84	L	3
11 Can. Maj	2045	7 40.8	+11 01	5.3	Ao	6	58 + 1	σ	......
13 ρ Hydrae	2361	8 43.1	6 12	4.4	Ao	103	....	B	4
53 l Leonis	2883	10 44.0	11 04	5.3	Ao	53	60 −150	B	5
57 Urs. Maj	3023	11 23.7	39 53	5.3	A2	56	31 49	B&σ	6
44 i Boötis ft	3846	15 0.5	48 2	6.2	Go	9	6 40	σ	7
69 e Herculis	4391	17 14.2	37 24	4.8	A2	17	12 23	L	......
39 b Draconis	4671	18 22.5	58 45	4.9	A2	4	80 −143	Monk	8
14 Cygni	5024	19 36.2	+42 35	5.4	B8	3	+31 +11	σ	9
11 δ Delphini	5323	20 38.8	14 43	4.5	A5	95	20 0	F	10
+85°383 Ceph	5784	22 21.3	85 36	5.4	Ao	4	30 −10	σ	11
+67°1562 Ceph	6108	23 43.1	+67 15	5.0	Ao	7	+26 − 4	B	......

B = S. B. Barrett; F = E. B. Frost; L = O. J. Lee; Monk = G. S. Monk; σ = O. Struve.

REMARKS

1. λ 4481 fair.
2. Two components measured.
3. Independently announced by Hnatek, *Astronomische Nachrichten*, **195**, 171, 1913.
4. The spectrograms of this star have been loaned to Dr. Otto Kohl, of Goettingen, who obtains from his measures a period of 8^d24, $e = 0.12$, $K = 22$ km/sec.
5. Two components measured. σ finds period 0.7 day.
6. σ finds $P = 12^h$.
7. Duplicities strongly suspected. Additional plates were kindly loaned by the Victoria and Mount Wilson observatories. The lines of this star are exceedingly wide and have a hazy appearance. The lines of the bright component of this visual binary are sharp.
8. Two components measured. Maximum separation from three plates, 150 km. Now under observation. Twenty-three more spectrograms have been obtained.
9. Lines very good.
10. No period could be established.
11. Duplicities strongly suspected.

The table is self-explanatory. The visual magnitudes and the spectral types are taken from the Harvard publications.

EDWIN B. FROST

YERKES OBSERVATORY
June 3, 1924

THE SPECTROSCOPIC BINARY 2 MONOCEROTIS

BY C. T. ELVEY

ABSTRACT

Spectroscopic binary 2 Monocerotis.—From thirty-two plates taken over the period September, 1912, to January, 1923, the following *elements of the orbit* were obtained: P, 9.3553 days; γ, +22.2 km/sec.; e, 0.208; K, 57.1 km/sec.; ω, 35°41; T, J.D. 2,419,673.815; $a \sin i$, 7,200,000 km; m_2/m_1, 0.86. The *secondary component* was visible only on the best plates of maximum and minimum velocities and was used only to obtain the mass ratio.

The spectroscopic binary 2 Monocerotis, $\alpha = 5^h54^m.3$, $\delta = -9°34'$, was discovered at the Yerkes Observatory in 1914 by S. B. Barrett, who announced it in *Popular Astronomy*,[1] with a period of 9.36 days and a range of 120 km/sec. The secondary component was suspected as being present. Twenty-six plates had been measured by Mr. Barrett in 1919, establishing a period of 9.355 days. He was unable to continue with the star because of other duties at the Observatory, so he graciously gave it to the writer for completion.

The spectral type according to the *Henry Draper Catalogue* is A5, and its photometric magnitude is 5.10. The primary spectrum is very good, having many sharp lines. The secondary is very faint, appearing only on the best plates of maximum and minimum velocities. The type of the secondary seems to be approximately the same as that of the primary.

Six additional plates were obtained at critical positions of the orbit during the winter of 1922 by Mr. Struve. This makes a total of thirty-two plates, all of which are of one-prism dispersion except-

[1] *Op. cit.*, **22**, 234, 1914.

ing one of three-prism. The period covered by the observations is from September, 1912, to January, 1923 (Table I).

TABLE I

THE OBSERVATIONS

No. of Plate	Obs. By	Meas. By	Date, G.M.T.		Phase*	Primary				Secondary	
						No. of Lines	Wt.	Vel.	Resid. O.−C.	No. of Lines	Vel.
1 B 3099....	B	Lv	1912, Sept.	$30^d 21^h 55^m$	3.089	4	1	−30.4	− 3.7	2	+ 76
3106....	L	B	Oct.	4 22 42	7.114	3	1	+34.0	13.1	.....	......
3242....	B	Lv	1913, Jan.	17 15 02	8.892	9	4	94.5	− 0.3	4	− 52
3258....	L	Lv		24 15 43	6.552	10	3	+25.2	+ 0.5	.....	......
3263....	M	B		29 16 15	2.246	15	3	−12.8	0.4	.....	......
3268....	L	Lv	Feb.	3 16 02	7.207	5	4	+51.7	+ 0.6	4	11
3275....	B	Lv		5 13 31	9.079	4	3	89.7	− 1.6	4	52
3276....	B	Lv		5 14 57	9.173	7	3	82.4	6.4	5	58
3277....	B	Lv		5 16 20	9.266	6	2	+82.5	3.3	5	− 53
3286....	M	B		7 14 09	1.778	10	3	−14.0	14.4	2	+ 88
3293....	B	Lv		13 14 44	7.769	8	3	+67.2	7.4	8	− 52
3299....	B	Lv		24 12 41	0.000	6	3	80.9	1.5	6	48
3308....	M	Lv	Mar.	5 13 10	9.079	5	2	+80.3	−11.0	3	65
3313....	B	B		10 14 22	4.680	5	1	−13.1	+ 9.4	.....	......
3322....	B	B		21 13 18	6.271	5	2	+24.5	9.8	.....	......
3340....	L	B	Apr.	15 13 43	3.276	3	1	−23.6	+ 4.5	.....	......
3681....	F	Lv	1914, Mar.	4 13 10	8.143	3	2	+74.9	−12.6	3	51
3682....	B	B		9 14 00	3.838	1	1	−23.4	+ 5.6	.....	......
3699....	F	B		16 14 19	1.498	5	2	+ 6.7	− 4.1	.....	......
5420....	Wk, B	B	1918 Nov.	11 19 38	0.000	7	1	83.1	+ 0.7	4	46
5437....	B	B	1919, Jan.	24 14 18	8.330	7	1	+79.7	−12.4	2	− 39
5452....	B	Lv	Feb.	7 14 20	3.650	5	3	−17.4	+11.8	4	+107
5468....	B	Lv	Mar.	7 12 52	3.463	5	3	−23.0	5.9	4	90
5624....	B, Pr	B	Nov.	3 20 36	1.591	6	2	+18.0	+10.8	.....	......
5640....	B, Pr	B		21 21 28	0.936	5	2	27.3	− 9.3	.....	......
5646....	Pr, B	Lv	Dec.	15 19 33	6.084	8	4	19.0	+10.4	.....	......
6652....	σ	Lv	1922, Nov.	6 20 41	6.178	9	4	+21.4	9.8	.....	......
6674....	σ	Lv	Dec.	11 17 40	3.463	11	3	−27.0	1.9	7	97
6681....	σ	Lv		18 19 54	1.219	8	2	+37.5	14.5	.....	......
6691....	σ	Lv		22 19 23	5.242	8	3	−13.0	+ 0.1	.....	......
6707....	σ	Lv	1923, Jan.	15 16 56	1.030	8	3	+18.4	−13.5	.....	......
B 970....	σ	Lv	1922, Nov.	24 20 56	5.429	4	5	− 4.5	+ 4.5	4	+ 59

* Based on definitive period and time of periastron passage.

In the second and third columns, B = S. B. Barrett, F = E. B. Frost, L = O. J. Lee, Lv = C. T. Elvey, M = S. A. Mitchell, Pr = J. Paraskévopoulos, σ = Otto Struve, and Wk = Miss E. W. Wickham; and Mr. F. R. Sullivan assisted at the telescope.

The plates were re-examined for the secondary component. Twelve of the plates, showing only the primary component, were not remeasured since the measures of the primary checked very well with Mr. Barrett's.

The lines measured are listed in Table II:

TABLE II

Primary Element	λ	Secondary Element	λ
Fe	4045.975	*Fe*	4045.975
Fe	4063.759	*Fe*	4063.759
Fe	4071.908	*Fe*	4071.908
Sr	4077.885	*Sr*	4077.885
Ti	4163.818	*Fe*	4202.198
Fe	4202.198	*Ti*	4468.663
Ti	4468.663	*Mg*	4481.400
Mg	4481.400	*Ti*	4549.767
Ti	4501.445		
Ti	4549.767		
Ti	4563.939		
Ti	4572.156		

Table III contains the normal points which were formed from the original measures. The velocity curves of both components are shown in Figure 1.

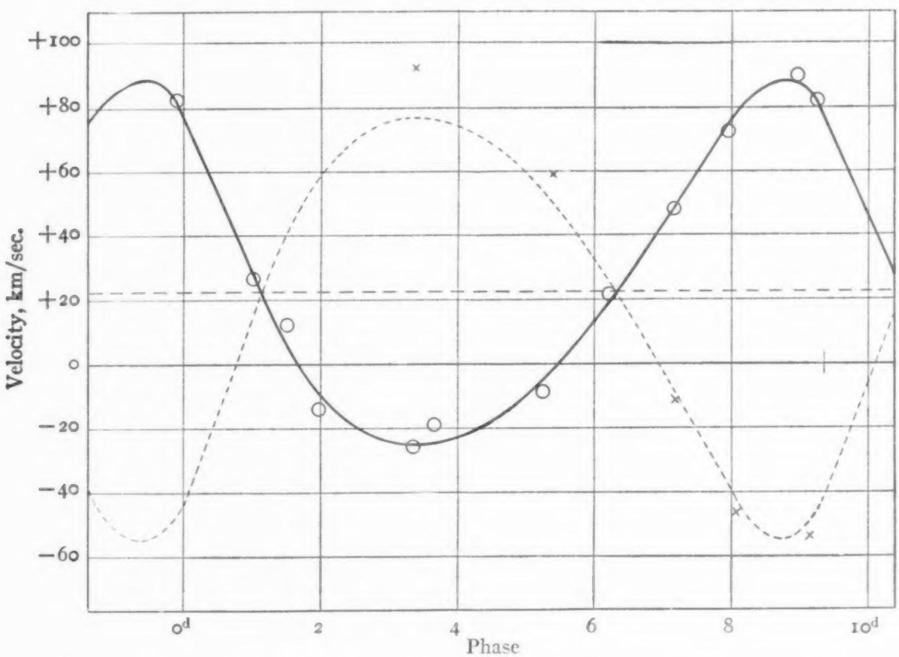

FIG. 1.—Velocity curve of the spectroscopic binary 2 Monocerotis. (Periastron coincides with phase 0^d.)

The preliminary orbit was obtained by the method of Lehmann-Filhés, and was corrected by least-squares solution with the aid of Schlesinger's tables. Table IV contains the elements, their corrections, and the probable errors.

TABLE III

No.	Phase	Wt.	Obs. Vel.	O.–C.
1	1^d029	0.7	+26.3	−2.1
2	1.516	.4	+12.4	+6.1
3	1.983	.6	−14.0	−5.0
4	3.359	.8	25.6	−0.4
5	3.667	.4	19.0	+5.5
6	5.248	0.9	− 8.7	−4.1
7	6.221	1.3	+21.9	+2.8
8	7.157	0.5	48.2	−0.6
9	7.952	.6	72.5	−2.7
10	8.963	.9	90.0	+2.2
11	9.243	0.9	+82.2	+0.2

TABLE IV

	Preliminary Elements	Correction	Definitive Elements	Probable Error
P	9.3553 days	....	9.3553 days	....
γ	+21.8 km/sec.	+ 0.4	+22.2 km/sec.	....
e	0.194	+ 0.014	0.208	±0.005
K	62.6 km/sec.	− 5.5	57.1	1.66
ω	16°9	+18°51	35°41	1°6
T	J.D. 2,419,673.41	+ 0.405	J.D. 2,419,673.815	±0.040
$a \sin i$	7,900,000 km	....	7,200,000 km	....

The least-squares solution changed the sums of the residuals times their weights from 267 for the preliminary to 80 for the definitive orbit.

The measures of the secondary component were not included in the solution because of the faintness of the lines. The mass ratio was obtained by plotting the velocity of the primary against the corresponding velocity of the secondary and computing the slope of the line through the points. The ratio thus obtained is

$$m_2/m_1=0.86.$$

UNIVERSITY OF KANSAS
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